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INSTRUCTION BOOK

for

MODEL FM-6B

VHF FREQUENCY METER

Gertsch

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GERTSCH PRODUCTS, Inc.

3211 SOUTH LA CIENEGA BOULEVARD, LOS ANGELES 16, CALIFORNIA • UPTON 0-2761 - VERMONT 9-2201

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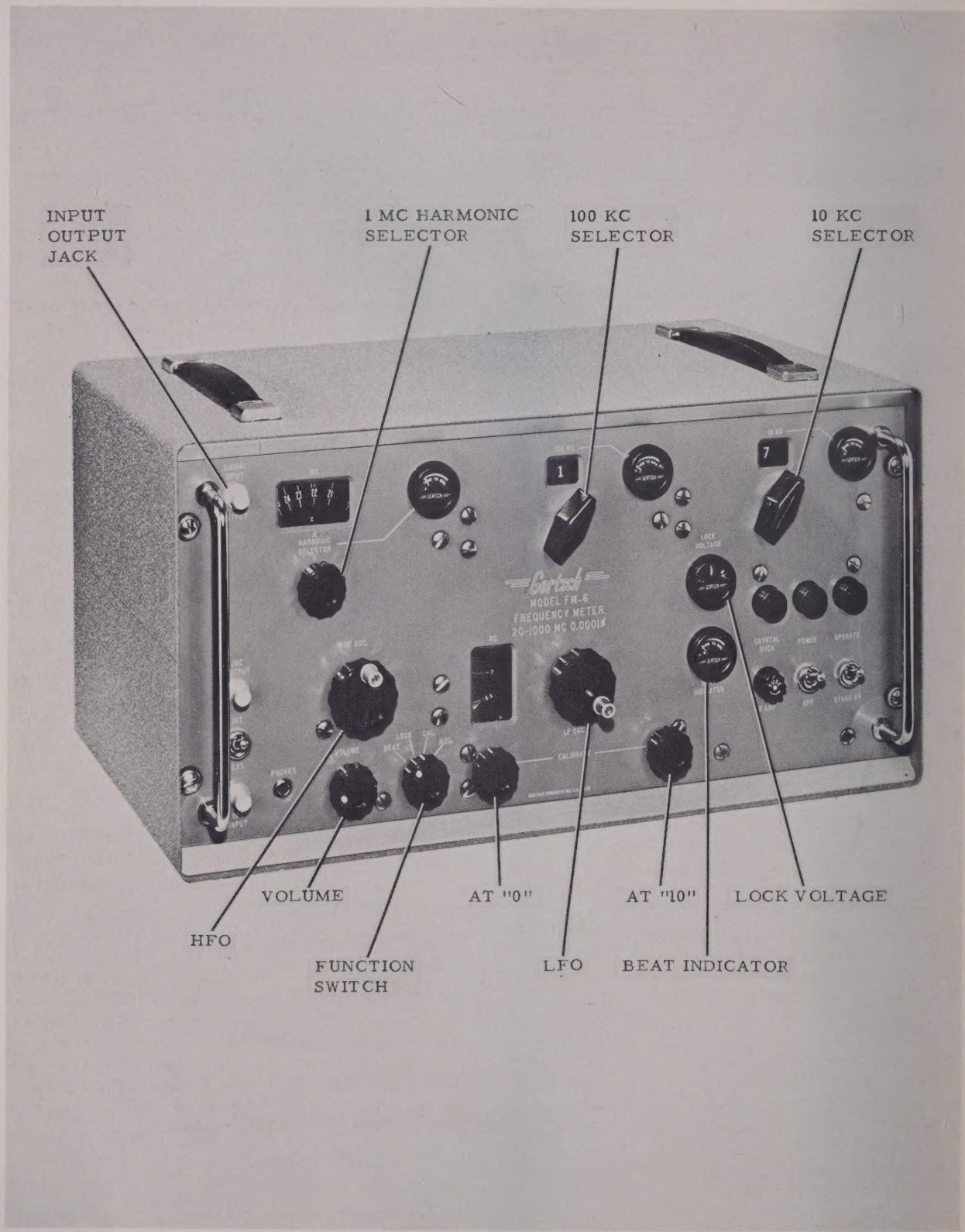


FIG. 1. OPERATING CONTROLS

SECTION I
GENERAL DESCRIPTION

This instruction book contains information on the FM-6 frequency meter in sufficient detail to permit the operation, adjustment, and maintenance that may be encountered.

The FM-6 has been designed to provide the ultimate in ruggedness and serviceability. The unit is constructed on 6 cast aluminum compartmented chassis units mounted on a heavy aluminum front panel. Chassis units are easily removable for service.

The instrument is supplied in two models. The FM-6 is the basic unit mounted in a cabinet having a removable front cover for dial and knob protection. The FM-6R is the basic unit for rack mounted use and is supplied without the case and front cover.

The following paragraphs briefly describe features of the FM-6, however, a more detailed explanation of the theory of operation can be found in Section III. The instrument has been designed to provide trouble-free operation and if maintenance is required, the information contained in Section IV will provide the user or a competent maintenance facility with sufficient information to perform all maintenance that may be encountered.

1. ACCURACY

The Model FM-6 has a guaranteed accuracy of 0.0001% (one part per million) when used to measure or generate any frequency within its range. By using a 100 kc frequency counter connected to the LFO (low frequency oscillator) output jack, the ability to read the LFO dial is no longer a factor and the accuracy is increased to ±0.00001% (one part in ten million). Even greater accuracy may be obtained by the use of an external 1 mc primary reference standard.

2. STABILITY

The frequency synthesis system used, combined with a wide range automatic frequency lock-in circuit, produces an instrument with a stability of ±0.0001% using the built-in 1 mc crystal standard. After "warm up", the instrument can be set to any frequency within its range and will maintain the generated frequency constantly with the above accuracies.

3. WIDE FREQUENCY RANGE

The instrument has a conservative frequency range of 20-1000 mc. It is a harmonic device with a fundamental range of 20-40 mc. Frequencies up to and beyond 1000 mc may be measured and generated by means of harmonics of the fundamental range; however, above 1000 mc, the amplitude falls off and special techniques may be necessary. Measurements have been obtained with this instrument as high as 2400 mc. Frequencies below 20 mc can be measured (but not generated) by using a harmonic of the unknown frequency. For example, a 5 mc signal may be measured by using its fourth harmonic.

4. CALIBRATION AGAINST PRIMARY STANDARDS

The basic accuracy of the FM-6 is determined by a precise, hermetically sealed, 1 mc crystal mounted in a precision oven maintained accurately to a given temperature in the 85°C. range. Provision is made for adjusting the internal crystal frequency without removing the unit from its case.

5. FCC FREQUENCY MEASURING REQUIREMENTS

Measurement in the VHF and UHF bands to the new FCC tolerance requirement of ±0.0005% is met with a minimum safety factor of 5 to 1.

6. DIRECT READING

Frequency is read directly from the dials and indicating windows (ELIMINATING THE NECESSITY FOR CHARTS, CURVES OR CALIBRATION BOOKS).

7. SIMPLICITY OF OPERATION

In operating, only a rough zero beat with the unknown signal is required with the megacycle dial. The 100 kc and 10 kc dials are decade switched from 0-9 and the proper point is indicated by a maximum reading on indicating meters. Final zero beat is obtained with the KC dial, with the aid of a zero beat indicating meter. Only one zero beat in the range of the KC dial can be obtained for a given input frequency.

8. PORTABILITY

The Model FM-6, even though a very precise measuring instrument, has been specifically designed for portability. A removable metal front cover is supplied to protect dials and knobs. A heavy weatherproof canvas carrying bag is available as an accessory item.

PERFORMANCE CHARACTERISTICS AND SPECIFICATIONS

1. FREQUENCY RANGE
   (A) Measurement 20 MC to 1000 MC. Harmonics of the unknown frequency may be used to measure below 20 MC
   (B) Generation 20 MC to at least 1000 MC
2. ACCURACY
   With ambient temperature between —15°C and +55°C: ±0.0001%
3. STABILITY
   ±0.0001%
4. FREQUENCY RESETABILITY
   ±0.00005%
5. SENSITIVITY
   10 MV input for 1 MW audio output (across 600 ohms) conncted for low impedance
6. READOUT
   Direct frequency readout for both measurement and generation — no charts or curves
7. BEAT INDICATOR
   Both aural and visual, by means of a panel meter indicator
8. LFO OUTPUT
   (for reading counter)
   (A) Range: 40-50 KC
   (B) Output: 0.5 V rms across 500 ohms
   (C) Output Connector: BNC jack at rear of instrument
9. R. F. OUTPUT
   (A) Fundamental Range (20-40 MC): 400 MV across 50 ohms
   (B) Harmonics (40-1000 MC): 2 MV minimum across 50 ohms
10. MODULATION
    30% at 1000 cps
11. 1 MC STANDARD OUTPUT
    (A) Amplitude: 1.0 V rms across 10 K ohms
    (B) Accuracy: 1 MC ± 0.1 cps
    (C) Stability: 1 part in 10^7. Above at any temp between —15°C and +55°C
    (D) Output Connector: Front Panel BNC jack
12. 1 MC Input Level Required
    (When using with external crystal standard) 1 Volt rms
13. PORTABILITY
    Accessory canvas carrying case available for easy carrying and protection. A removable metal front cover protects meters, knobs, etc.
14. POWER REQUIREMENTS
    75 Volt Amperes 115 or 230 VAC 50-60 cps
15. SIZE
    Rack 19 x 8-3/4 x 11 deep
    Case: 19-1/4 x 9-3/4 x 13-1/4 deep with front panel cover in place
16. WEIGHT
    Approx. 40 lbs.

SECTION II
OPERATION AND ADJUSTMENT

1. FUNCTION OF EQUIPMENT.

The model FM-6 direct reading VHF Frequency Meter will measure or generate any frequency within the range of 20-1000 mc. with a minimum accuracy of 0.0001%. They can also be used below 20 mc. as described in this section.

2. READING THE DIALS.

In the model FM-6 the frequency is read directly on the dials. The HFO dial will read the megacycles, the 100kc dial the hundreds of kilocycles, the 10kc dial the tens of kilocycles and the LFO dial the remaining digits (0 to 10kc).

It is important that the dial readings correlate each other. For example, if the instrument is set to 23.999 mc, the HFO dial must be very close to 24 mc and the 100kc, 10kc and LFO dials should read 999 respectively. The 1 mc harmonic selector dial in this case should be set to 23. This is the only correct setting to obtain this instrument frequency. It may be possible that the frequency of the HFO does not agree exactly with the dial calibration. In the previous example, the HFO dial might possibly read over 24 mc but the instrument reading will still be correct if attention is paid to the reading as a whole. In this case it obviously cannot be 24.999 mc since the HFO dial is very close to 24 mc and the other dials 999 with the 1 mc harmonic selector dial at 23. Therefore all dial readings must correlate each other.

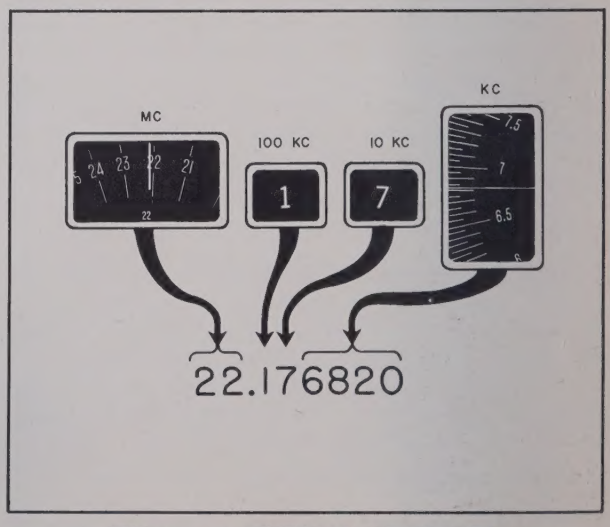


FIG. 2. A TYPICAL READOUT

A. HOW TO MEASURE A FREQUENCY.

(1) Connect the signal to be measured to the *input-output* jack.

(2) Place function switch in the beat position.

(3) Rotate the H.F.O. dial to obtain a zero beat with head phones.

(4) Select the proper 1 MC harmonic as follows: The number appearing in the harmonic selector window must be the lower of the two numbers between which the H.F.O. dial pointer lies. For example, if the pointer is between 22 and 23, the number to be placed in the window is 22. Tune for maximum indication on the harmonic selector meter.

(5) Rotate the 100 KC selector switch to get maximum deflection on the meter.

(6) Rotate the 10 KC selector switch to get maximum deflection on the meter.

(7) Move the function switch to *lock* position.

(8) Rotate the H.F.O. dial *slightly* to make certain that lock has been established. This will be indicated by the lock meter following the movement of the H.F.O. dial. The meter is then set to and left at center position.

(9) Rotate the L.F.O. dial to re-establish zero beat. If the measured signal is of sufficient amplitude, the beat indicator meter will enable the beat note to be seen to below one cycle per second.

(10) The frequency being measured (or harmonic) is then read from the dials as in the following example.

MC (HFO)	100 KC	10 KC	KC (LFO)
22	1	7	6820

Which is 22.17682 MC.

B. HOW TO GENERATE A FREQUENCY.

When measuring a frequency with the FM-6, the H.F.O. is caused to generate a frequency (or harmonic) identical to that being measured. Any frequency between 20 and 40 MC (to 1000 MC on harmonics) can be generated in a similar manner as follows:

(1) Set the dials (H.F.O., 100 KC, 10 KC and L.F.O.) to the desired frequency.

(2) Select the correct 1 MC harmonic on the harmonic selector dial as explained in Paragraph 4 of "Frequency Measurement".

(3) Slowly rotate the H.F.O. dial to obtain maximum deflection on the 100 KC and 10 KC meters.

(4) Place the function switch to lock position and continue rotation until lock is established as indicated by the lock meter suddenly following the H.F.O. dial movement.

(5) Re-adjust H.F.O. dial to bring the lock meter to center position and the frequency set up on the dials is now available at the input-output jack.

The direction of H.F.O. dial rotation to obtain lock depends upon the initial dial setting. If lock cannot be obtained by a small rotation in one direction, the direction should be reversed.

(1) Set FUNCTION SWITCH to CAL. position.

(2) Set the L.F.O. dial to 10 and adjust the control marked "AT 10" for a zero beat using the beat indicator.

(3) Rotate the L.F.O. dial to 0 and adjust the control marked "AT 0" for a zero beat as in Step 2.

(4) Repeat Steps 2 and 3 until both ends of dial are correct. The order of adjustment as listed above (first 10 and then 0) will be found to give the quickest results.

D. METHODS OF COUPLING.

The method of coupling to the Frequency Meter depends upon the type of source being measured as well as the relative output of the source being measured. In the case of a signal from a transmitter or oscillator, sufficient coupling will be obtained in most cases with the antenna plugged into the Frequency Meter and using the near radiation field from the transmitter. For signal generators and other weak signal devices, direct coupling to the input-output jack via a matched coaxial line is recommended. In this manner signals may be measured throughout the entire frequency range whose voltage magnitude is at least 1000 microvolts. In the case of signals considerably weaker than this the use of an auxiliary receiver to obtain the measurement is recommended. In this case the procedure will be as follows:

(1) Locate the frequency to be measured on the receiver.

(2) Provide suitable coupling between the receiver and the Frequency Meter.

(3) Tune the H.F.O. oscillator until a beat note is heard in the receiver.

(4) Change the receiver tuning slightly and note whether or not the beat note frequency changes. If the beat note frequency changes the response is an image response or a response with a local oscillator harmonic or other type of spurious receiver response. If this is the case, continue tuning the high frequency oscillator until a proper response is obtained, that is, one in which the beat note frequency does not vary for slight receiver tuning changes.

(5) Proceed with frequency measurement as in paragraph 3A steps 1 through 10 using the receiver as the beat detector.

4. ADDITIONAL NOTES ON OPERATION.

(1) When the FM-6 is in the locked condition, the lock-in will hold over the entire range of the L.F.O. if the lock voltage meter is reasonably centered by adjustment of the H.F.O. dial.

(2) Accurate measurements and output frequencies will be obtained when and only when the instrument is in the "lock-in" condition.

(3) For maximum accuracy, always use the aligned double lubber line method of eliminating parallax on the L.F.O. dial.

5. USE AT LOWER FREQUENCIES.

The Frequency Meter may be used for measuring frequencies below 20 mc. The only requirements are that the source being measured have sufficient harmonic output so that harmonics fall within the fundamental, that is 20 - 40 mc., range of the instrument. This require-

ment can readily be met by most transmitters and if it cannot be met, harmonics can be generated by means of a diode type distortion device. The method of operation is identical with the method of measuring a frequency within the range of the instrument. However, when the final frequency measurement has been made, the dial readings must be divided by the order of the harmonic being measured. For example, if the transmitter being measured has a fundamental frequency of 7.215 mc. the measurement can be made at the third harmonic, which would be 21.645 mc. When this reading of 21.645 mc. has been obtained, it must be divided by 3 to obtain the transmitter frequency. The same accuracy is maintained as in the normal operating range of the instrument.

6. AUXILIARY OUTPUT.

In addition to the normal output of the Frequency Meter, that is, 20 to over 1000 mc. there also is available the output of the low frequency oscillator (40 to 50 kc) from a BNC connector in the rear of the L.F.O. chassis. This output can be used to drive a counter to obtain a greater accuracy in frequency measurement or generation. The counter reading subtracted from 50 kc is the last four digits of the frequency of the FM-6.

The output of the 1 mc. crystal oscillator is also available on the front panel for use as a secondary standard. The specifications of this output are given in the overall specifications table on page 6.

7. METHOD OF DETERMINING THE FREQUENCY OF AN ENTIRELY UNKNOWN SOURCE.

A. FREQUENCIES KNOWN TO BE ABOVE 20 MEGACYCLES.

The method to be described requires only that the source be known to be above 20 mc. Procedure is as follows:

(1) Using the standard measuring procedure and starting at 20 mc. with the H.F.O., tune the H.F.O. through the entire range and pick out the first strongest beat note against the unknown signal. Measure this frequency very carefully and call it f_1.

(2) Continue tuning upwards in frequency with the H.F.O. until the next response having the beat note of approximately the same intensity is found. Measure this frequency and call it f_2. If only one response has been found of high signal intensity, then the frequency being measured is in the fundamental range of the instrument, that is 20 to 40 megacycles (or 40 to 60 mc. on second harmonic if beat note falls between 20 and 30 mc.) These two cases may be distinguished by the fact that the beat note changes frequency twice as fast as the tuning of the low frequency oscillator if the response is on second harmonic.

(3) If two responses have been found then it is obvious that the first response occurs at a frequency $nf_1 = x$ where n is some integer representing the harmonic being used and x is the unknown frequency, and similarly, since the Frequency Meter was tuned upwards in frequency to the next harmonic response, this response would occur at $(n-1)f_2 = x$ where $n-1$ indicates that the next lower harmonic of the Frequency Meter was being used when f_2 was measured. Solving these equations for n we obtain $n = \frac{f_2}{f_2 - f_1}$. Having substituted the actual measurements into this equation, n will come out to be very close to some integral value. Choosing the closest integral value for n the unknown frequency is then this integer times f_1 or $x = Nf$ where N is the closest integral value to the n calculated by the equation above.

B. FREQUENCIES KNOWN TO BE BELOW 20 MEGACYCLES.

(1) Starting at 20 mc., tune the H.F.O. throughout its range and select the first loudest response. Measure this frequency carefully and call it f_1.

(2) Continue tuning upwards in frequency until the next response of approximately the same intensity has been obtained. Measure this and call it f_2. If no second response can be obtained, then the response is a second harmonic response and the frequency of the unknown would be $\frac{f_1}{2}$.

(3) If a second response was obtained, then it is obvious that the first response was obtained at a frequency $nx = f_1$, where n is an integer representing the harmonic of the source that was used in the measurement of f_1 and similarly, the second response would occur at $(n+1)x = f_2$ indicating that the next higher harmonic of the source was used in the second measurment. Solving these equations for n we obtain $n = \frac{f_1}{f_2 - f_1}$. Substituting the actual measurements into this equation, n will come out to be very close to some integral value. choosing the closest integral value to the n obtained and substituting into the equation above, we obtain $x = f_1/N$ where N is the integral value obtained above.

SECTION III
THEORY OF OPERATION

1. GENERAL.

With reference to the block diagram, it may be seen that the portion outlined by dotted line comprises a simple heterodyne frequency meter. Unknown signals are fed into the BEAT DETECTOR and compared against the fundamental or harmonic output of the HF OSC. and BUFFER. The resultant zero beat is amplified and presented by both aural and visual means. Since the HF OSC. dial is calibrated in 1 MC increments only, to obtain a reading accuracy of 1 part per million, a means of interpolating between the 1 MC points must be provided.

In the FM-6 a stable frequency base is provided by the use of a 1 MC CRYSTAL OSC., the stability of which is better than one part in 10^7. Harmonics of this oscillator are available from the 23rd to the 42nd by means of a tunable harmonic amplifier. Heterodyne action between the H.F.O. and the proper 1 MC harmonic produces an IF frequency always between 2 and 3 MC. For this example the H.F.O. is set to a frequency of 22.176820 MC and the 25th harmonic of the 1 MC oscillator is selected, resulting in a difference frequency of 2.82318 MC.

The first IF amplifier frequency is pre-tuned in 100 KC steps from 2.95 to 2.05 MC, and selected by means of the 100 KC decade switch, positions 0 to 9. In operation the 100 KC switch is rotated for maximum output, as indicated on the 100 KC meter. Since the frequency of interest is 2.82318 MC an IF frequency of 2.85 MC (Position 1) would produce maximum output.

The 1 MC oscillator output is divided by 10 twice so that 100 KC and 10 KC signals are available. As the first IF amplifier was tuned with the 100 KC switch, a harmonic of the 100 KC was selected so that a second IF frequency between 300 and 400 KC would be produced. In this example, the 32nd harmonic of 100 KC (3.2 MC) mixing with the output of the first IF amplifier (2.82318 MC) produces a 2nd IF frequency of .37682 MC. In a similar manner, the second IF amplifier is pre-tuned to 10 frequencies from 305 to 395 KC in 10 KC steps. The 10 KC decade switch is rotated until a maximum output is indicated on the 10 KC meter. Since the frequency of interest is .37682 MC an IF amplifier frequency of .375 MC (Position 7) will result in maximum output.

Again, as this second IF amplifier is tuned a harmonic of the 10 KC is selected so that a third difference frequency between 40 and 50 KC is generated. To produce this 3rd IF frequency of 43.18 KC the 42nd harmonic of 10 KC (.42 MC) was mixed with the output of the 2nd IF amplifier.

The output of the 3rd IF amplifier is compared in a phase discriminator with a continuously variable LOW frequency oscillator. Any phase difference becomes an AFC signal to correct the H.F.O. This loop then phase locks the H.F.O. The stability of the system is a function of the stability of the 1 MC oscillator and the L.F.O. Since the L.F.O. may be calibrated against the crystal, the stability then approaches that of the 1 MC crystal oscillator.

Harmonics of the 20-40 MC H.F.O. are used to zero beat against higher frequency, enabling frequency measurement and generation far beyond the fundamental range.

2. DETAILED DESCRIPTION.

A. HIGH FREQUENCY OSCILLATOR AND 1 MC HARMONIC AMPLIFIER.

The H.F.O. (V104) is a Hartley E.C.O., continuously variable from 20 mc to 40 mc by capacitor C118.

A voltage sensitive silicon capacitor (CRC101), across part of the tank circuit provides automatic frequency control when the oscillator is locked to the L.F.O.

The A.F.C. voltage on the lock line controls the bias on CRC 101 which determines its effective reactance as presented to the tank circuit. The potentiometer R114 is geared to the main tuning capacitor shaft to automatically reduce the A.F.C. voltage proportional to capacitor rotation. This produces an approximately equal locking range throughout the H.F.O. tuning range.

V105 is the buffer-output amplifier and the RF output is from the secondary of the tuned transformer T103 through J104 to the mixer-detector board in the audio chassis and from there to the input-output jack J701 on the front panel. The screen voltage for V 105 is obtained from the audio chassis where it is caused to vary at a 1 KC rate when the function switch is in the modulation (MOD) position, thus modulating the RF output.

The 1 mc harmonic generator V101, supplies two outputs when driven with a 1 mc signal. The output from the secondary of the tuned transformer T101 in the suppressor grid circuit is used to drive the decade divider V201 in the 100 KC chassis.

The plate signal, a 1 mc pulse of high harmonic content, is fed to the synchronously tuned harmonic selector (V102) and amplifier (V103) from which the 23rd to 42nd harmonics are selected by the tuning capacitor C107.

The capacitor shaft of C107 is coaxial with that of C118 and a 1 mc harmonic selector control knob is located on the front panel. A coupling between the two shafts is provided such that the harmonic selector (C107) is carried to approximately the correct setting by the H.F.O. tuning capacitor C118, yet allowing an incremental adjustment to maximize the correct harmonic output.

The proper harmonic number (as explained in the

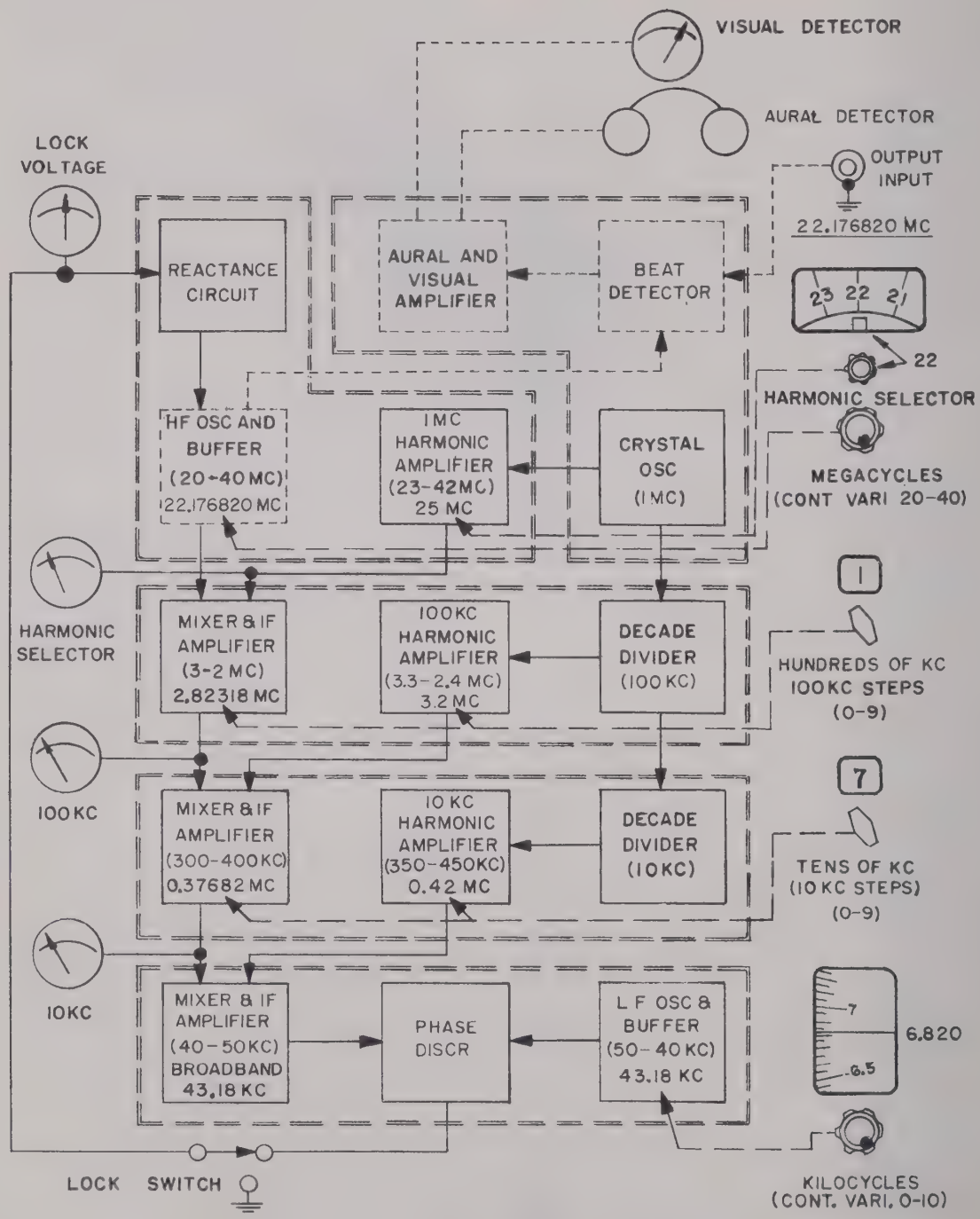


FIG. 3. BLOCK DIAGRAM

operating instructions) when caused to appear in the harmonic selector window must be adjusted for maximum output as indicated by meter M701, which measures the rectified 1 mc harmonic signal appearing in the 100 KC chassis on the grid of the mixer tube V201.

The number appearing in the harmonic selector window is not the actual harmonic but is offset by 3 for simplicity of operation. The harmonic to be used is that which when mixed with the H.F.O. frequency will produce an intermediate frequency between 2 and 3 mc.

The harmonic output is taken from the secondary of the tuned transformer T102 through J103 and mixed with the H.F.O. output from J105 in the 100 KC chassis.

B. 100 KC AND 10 KC SELECTOR CHASSIS.

The 100 KC and 10 KC selector chassis contain almost identical circuitry. The only important difference is the frequencies involved. The following description of the 100 KC selector chassis should also serve for the 10 KC selector chassis.

The plate circuits of the mixer tube V203 and the I.F. amplifier V204 are synchronously tuned by switch sections C and D of S201, over the frequency range of 3-2 mc in ten 100 KC wide steps. The switch consecutively adds the trimmer capacitors in parallel to cover this range.

One of the ten switch positions will pass the intermediate frequency produced by the mixing of the H.F.O. and the properly selected 1 mc harmonic. The number of the switch position (appearing in the window on the front panel) will be the hundreds of kilocycles of the measured or generated frequency.

The 4 gang switch S201 when rotated to the passband that accepts the intermediate frequency, automatically selects the correct 100 KC harmonic to be mixed with the output of V204 in the mixer V303 of the 10 KC selector chassis.

The decade divider V201 has an input of 1 mc (from an output of V101)and provides an output of 100 KC. The 100 KC square wave appearing in the plate circuit is differentiated and the resultant positive going pulse applied through the biased diode CR201 to the harmonic selector V202, tuned grid circuit. Switch sections S201A and S201B synchronously tune the grid and plate circuits in 10 steps to select and amplify the 33rd through the 24th harmonic of the 100 KC pulse.

A second output from the plate of V201 through R201 is the input to the decade divider (V301) in the 10 KC selector chassis.

Diode CR202, in the second control grid of V203, rectifies a portion of the 1 mc harmonic and the DC current through R214 to meter M701 indicates the proper adjustment of the 1 mc harmonic selector.

C. LOW FREQUENCY OSCILLATOR CHASSIS.

The Low Frequency Oscillator V403 is a transistron type oscillator variable over a frequency range of 40 to 50 KC by capacitor C423. Controls L403 and C421 are available on the front panel for calibration purposes. L403 is marked "at 10" and C421 "at 0". Proper adjustment of these controls will cause the frequency of the L.F.O. to be in exact relationship with the dial calibrations.

The L.F.O. output signal is taken from the capacitor divider C424 and C425 and fed to the phase splitter V404A, which in turn provides the driving signals for V405 whose push pull output is one input to the phase detector.

V401 is the mixer and V402 the I.F. ampliifer. The resonant circuits in the plates are stagger tuned to provide a bandpass of 10 KC.

The 10 KC harmonic and I.F. output from the 10 KC step chassis are mixed and with a correct selection in the preceding steps, will produce an intermediate frequency between 40 and 50 KC.

Diode CR401 rectifies a portion of the I.F. from the 10 KC step chassis and the resultant D.C. is indicated on Meter M703 as a measure of the amount of signal present.

The phase of the 40-50 KC intermediate frequency from V402 and the phase of the L.F.O. frequency from V405 are compared in the phase detector. With the function switch in the lock position, the detector output voltage controls the reactance of CRC101 in the 20-40 mc oscillator of the H.F.O. chassis. The 20-40 mc. oscillator frequency is caused to change by the amount necessary to make the 40-50 KC intermediate frequency exactly the same as that of the L.F.O. variation cycle for cycle over the 10 KC range.

Cathode follower V404B provides two L.F.O. outputs. One is available through J404, a B.N.C. connector in the rear of the FM-6, for use with an external counter to improve the read out accuracy.

The second output through J405 goes to the audio section of the crystal oscillator and audio chassis, where it is beat with the 10 KC signal for the L.F.O. calibration.

D. CRYSTAL OSCILLATOR AND AUDIO CHASSIS.

1. CRYSTAL OSCILLATOR.

Tube V504 is the crystal oscillator and V503 the buffer amplifier. The signal at the plate of V503 is rectified negative by CR505 and a portion of the DC voltage used as a bias on the crystal oscillator tube for automatic gain control. R517 controls the gain of V503 which determines the amount of a.g.c. developed versus crystal activity. R517 is adjusted to have a voltage of 0.6 V peak to peak at pin No. 1 of V504. C521 and C524 were selected such that when in parallel with C522 and C523 in approximately their mid range, the crystal will resonate at one megacycle ± .1 ppm. Sufficient adjustment remains to compensate for aging effects of the crystal.

Transformer T502 supplies an output of approximately 1 V RMS to the internal-external 1 mc switch S701 on the front panel. In either position of the switch the 1 mc output is available at J702.

The crystal oven has a 117 V A.C. heater and is not interrupted by the standby switch.

It is possible to maintain the oven temperature during transit (to avoid the necessary warm up time) by connecting the FM-6 to an inverter (6 or 12 VDC to 117 V AC) of the type made to plug into a cigarette lighter receptacle. When the power switch is in the 'on' position and the standby switch is in the 'off' position, the only power used is that of the crystal oven and indicator lamps. Any small inverter capable of supplying 15 watts at 117 V AC should be adequate.

2. AUDIO SECTION.

The audio section contains the mixer-detector board,

function switch, two stages of audio voltage amplification (V501), cathode follower (V502A), power output stage (V502B) and a lock voltage VTVM (V505).

The outputof the H.F.O. at J503 is applied to the harmonic generating diode CR501, and the signal is then mixed with the frequency present at J504 (input-output) and the beat note detected by diode CR502. The beat note is then fed to the beat note ampliifer by the function switch (S501) in the beat and lock positions.

A harmonic rich 10 KC signal from the decade divider (V301) and the L.F.O. output frequency are also supplied to the mixer-detector board through J502 and J501. In the calibrate position (CAL) of the function switch, the two signals are mixed and the beat note detected by diode CR503 then fed to the beat note amplifier. An RC filter (R505 and C504) is used to reduce the 10 KC signal present in the output of the detector.

The beat note, after amplification by V501, is direct coupled to the first half of V502, a cathode follower. The beat note signal present at the cathode is then capacity coupled to the beat indicator meter M705 which will visually indicate the beat note signal to far below the audible range. Diode CR504 is used to provide DC restoration for the meter.

The reduced signal at the junction of R511 and R538 is capacity coupled to the volume control (R513) to drive the audio output stage V502B.

The function switch (S501), when in the modulation (MOD) position, converts the output stage to a blocking oscillator. The wave shape is modified to approximate a sine wave by an RC network in the feedback path and the resultant signal at the plate is used to screen modulate the H.F.O. buffer stage.

The lock position of the function switch is identical to the beat position except that the short to ground on the lock line is removed by S501F. V505, the lock voltage VTVM will now indicate the amount and polarity of the A.F.C. voltage present to maintain the correct frequency of the H.F.O. Control R535 is used to adjust the meter to center position when the function switch is in any but lock position.

E. POWER SUPPLY.

Plate and heater power (except crystal oven) for the FM-6 is provided by a single power transformer T601. The primary is wound with two equal 115 V windings that can be connected either in parallel for 115 V operation or in series for 230 V operation. Binding posts and straps are provided for a simple change over to either voltage.

The 220 V AC from the secondary winding is rectified by four plug-in type silicon rectifiers in a full wave bridge circuit.

Standby switch S602 interrupts the 220 V AC to the bridge rectifier and the 6.3 V AC to all tube heaters but allows the crystal oven heater circuit to operate normally.

The D.C. voltage (+150 V nominal) furnished by the power supply is regulated. A gas diode V603 is the reference source and V602 is the D.C. amplifier. The series regulator V601 is shunted by R602 to reduce the amount of load current through it.

The regulation is necessary primarily to reduce the internal impedance of the supply preventing the low frequency beat note from being coupled to the other circuits in the FM-6. For this reason the actual voltage is not too important and precise adjustment is not needed.

The voltage should measure somewhere between +145 and +155 Volts.

The unit is normally connected for 115 V AC operation and is supplied with a 1 ampere fuse. If used on 230 V AC, the fuse should be changed to one of 1/2 ampere rating.

SECTION IV
MAINTENANCE

1. SELF CHECKING AND ALIGNMENT.

The FM-6 possesses many self checking features and it is possible to correct almost all minor misalignment due to tube changes, aging of components etc., without the need of additional test equipment.

A. HIGH FREQUENCY OSCILLATOR.

(1) Remove the 1 mc harmonic output tube (V103).
(2) Connect a short coaxial cable between the 1 mc output and the INPUT-OUTPUT jack.
(3) Connect a short clip lead across the 10K resistor that is in series with the 1 mc output jack.
(4) Rotate the H.F.O. dial and a beat note will be heard at every megacycle point.
(5) If dial tracking is off, adjust C120 and C130 at the 40 mc end and L105 and T103 at the 20 mc point.
(6) Replace V103 and set the 100 KC selector dial to zero.
(7) Set the 1 mc HARMONIC SELECTOR dial to 38 and the H.F.O. dial to 38 mc and rotate slightly to get maximum reading on the 100 KC selector meter.
(8) Adjust C130 to get a maximum 100 KC selector meter reading.
(9) Set the 1 mc HARMONIC SELECTOR dial to 22 and the H.F.O. dial to 22 mc as in Step 6.
(10) Adjust T103 to get a maximum 100 KC selector meter reading.

B. 1 MC HARMONIC SELECTOR.

With the 100 KC selector switch set at 5 and the H.F.O. dial set to approximately 22.5 mc, the 1 mc harmonic selector should cause a peak reading on the harmonic selector meter and 100 KC selector meter when the number 22 is centered in the window. Peak meter readings should also be obtained when the H.F.O. is set to 38.5 mc and the 1 mc harmonic has the number 38 centered. If the centering is off enough to warrant it, the following procedure can be used for re-alignment.

(1) Set the H.F.O. dial to 38.5 mc and center the number 38 in the 1 mc HARMONIC selector window.

(2) Set KC selector dial to 5.

(3) Adjust C108 and C114 to give maximum reading on the 1 mc HARMONIC selector meter. This should also produce a maximum reading on the 100 KC selector dial, which insures the correct harmonic has been chosen.

(4) Set H.F.O. dial to 22.5 mc and the 1 mc HARMONIC selector to center the number 22 in the window.

(5) Adjust L102 and T102 for maximum reading on the meters as in Step 3.

(6) Repeat Steps 1 through 5, if necessary.

C. 100 KC SELECTOR CHASSIS.

1. 100 KC SELECTOR I.F.

Set up and lock a frequency of 30.095 mc as per operating instructions. As the 10 KC selector is switched from 9 through 0 and locked on each setting, the 100 KC selector meter reading will indicate the bandpass of position zero of the 100 KC chassis I.F. The bandpass should be essentially symmetrical. Each 100 KC passband (positions 0-9) can be checked in this manner. If the bandpasses are too unsymmetrical, they can be realigned as in the following:

(1) Set up and lock the FM 6 to generate a frequency of 30.055 mc.

(2) Adjust the two I.F. trimmer capacitors marked 0, in the two groups of trimmers nearest the front panel, to give a maximum 100 KC selector meter reading.

(3) Reset the 100 KC selector switch to 1 and re-establish lock.

(4) Adjust the I.F. trimmer capacitors marked 1 as in Step 2.

(5) Continue to adjust each set of I.F. trimmers 0 through 9 in this order, as in Steps 2, 3, and 4.

2. 100 KC SELECTOR HARMONICS.

(1) Set up and lock a frequency of 30.055 mc on the FM-6.

(2) Adjust the two 100 KC harmonic selector trimmer capacitors marked 0 in the two groups of trimmers toward the rear of the chassis for a maximum reading on the 10 KC selector meter.

(3) Change the 100 KC selector switch to position 1 and adjust the H.F.O. to re-establish lock.

(4) Adjust the two 100 KC harmonic selector trimmer capacitors marked 1 as in Step 2.

(5) Continue to adjust each set of trimmers, 0 through 9, and in that order, as in Steps 2, 3 and 4.

This alignment may be performed in most cases even if the L.F.O. chassis is not functioning properly and a lock cannot be obtained. The frequency is set up the same as in Step 1 above and the H.F.O. is adjusted to give maximum output on the 10 KC selector meter each time the 100 KC selector is changed.

The use of the 10 KC selector meter indication (or lock, if possible) insures the correct frequency is being peaked each time. If the 10 KC selector chassis is not functioning properly, the alignment procedures outlined above will not work and some other means of measuring the intermediate frequencies and 100 KC harmonics will be necessary. A table showing the correct frequencies appears on the 100 KC selector chassis schematic Fig. 5.

3. 100 KC DECADE DIVIDER.

There are two methods to determine whether the decade divider is performing the proper division. A frequency counter can be used to measure the 100 KC output signal appearing on J201. This output is direct coupled to the plate of V201 through a resistor and the DC plate voltage will also be present. The second method is to connect an oscilloscope probe to the cathode (Pin No. 2) of V201. The waveform present is the sum of the input and output signals. There should be exactly 10 cycles of the 1 MC input signal appearing during the time for one cycle of the output signal (100 KC).

If either method indicates an incorrect division, L201 should be readjusted. As the L201 is adjusted it will be noted that a locking range exists where a small adjustment of the slug will not change the division rate. The limits of the locking range should be noted and the slug set to a position midway between the two.

The locking range should be at least ½ turn total on the 100KC coil and 1½ turns on the 10 KC coil. Due to the wide variations in 6AS6 transconductances, a positive bias is required to optimize the circuit operation for the widest possible locking range.

The optimum setting is best determined by observing the plate on Pin No. 5 with an oscilloscope. With the bias initially set to zero (maximum clockwise), increase the bias until the waveform shows an absence of sync signal (1 mc or 100 KC) on the positive excursion of the waveform. The bias can be anywhere between 0 and 1.5V and in most cases will be about 0.7V.

D. 10 KC SELECTOR CHASSIS.

1. 10 KC SELECTOR I.F.

Calibrate the L.F.O. and set up and lock a frequency of 30.595 mc as per operating instructions.

When the L.F.O. dial is rotated from 0 through 10 the bandpass of position 9 of the 10 KC chassis I.F. is indicated by the 10 KC selector meter and should be essentially symmetrical. Each passband (0-9) can be checked in this manner. If the passbands are too unsymmetrical, they can be realigned as in the following.

(1) Set up and lock the FM6 to generate a frequency of 30.595 mc.

(2) Adjust the two I.F. trimmer capacitors marked 9 in the two groups of trimmers nearest the front panel to give a maximum 10 KC selector meter reading.

(3) Reset the 10 KC selector switch to 8 and re-establish lock.

(4) Adjust the I.F. trimmer capacitors marked 8 as in Step 2.

(5) Continue to each set of I.F. trimmers 9 through 0 (in this order) as in Steps 2, 3 and 4.

2. 10 KC SELECTOR HARMONICS.

To peak the 10 KC selector harmonic amplifiers it will be necessary to have some auxiliary means to indicate the relative amplitude of the L.F.O. intermediate frequency. An oscilloscope capable of showing 40-50 KC at approximately 40 volts peak to peak or a high input impedance AC VTVM may be used.

The following procedure should be used.

(1) Set up and lock a frequency of 30.595 mc on the FM-6.

(2) Connect the oscilloscope or VTVM to the junction of C412, R411 and R414. These components are located on the terminal board on the rear wall of the L.F.O. chassis.

(3) Adjust the two harmonic selector trimmer capacitors marked 9 in the two groups of trimmers toward the rear of the chassis, for maximum indication.

(4) Change the 10 KC selector switch to position 8 and reset the H.F.O. to re-establish lock.

(5) Adjust the two harmonic selector trimmer capacitors marked 8 as in step 3.

6. Continue to adjust each set of trimmers, 9 through 0, and in that order, as in steps 3, 4 and 5.

If the L.F.O. chassis is not functioning properly and lock cannot be obtained, the alignment procedures outlined above will not work. Some other means of measuring the intermediate frequencies will be necessary. A table showing the correct frequencies appears on the 10 KC selector chassis schematic Fig. 6.

3. 10 KC DECADE DIVIDER.

The correct operation of this circuit can be determined in the same manner as that used for the KC decade divider and described in section C paragraph 3.

E. LOW FREQUENCY CHASSIS.

1. LOW FREQUENCY OSCILLATOR (LFO).

With the FUNCTION SWITCH in the CAL position, the two front panel controls (L403 and C421) should have sufficient range to bring the L.F.O. dial into calibration. If the controls do not have the necessary range, L404 and C423 must be re-adjusted.

After a half-hour warm up period, set both front panel controls to their mid-range and adjust L404 and C423 to obtain correct dial calibration.

2. BROAD BAND 40-50 KC I.F.

To realign the I.F. an oscilloscope or VTVM will be necessary to monitor the same point as for the 10 KC harmonic selector adjustments.

If the I.F. is not too far out of alignment and a lock can be obtained, rotating the L.F.O. dial from 0 to 10 will vary the I.F. from 50 to 40 KC. L401 is peaked at 51 KC and L402 at 39 KC.

In the case where alignment is such that the FM-6 will not lock, the L.F.O. output on J404 or J405 can be fed directly into the mixer tube (V401) through J402. After a rough alignment is made and the FM 6 will lock, the first method should be used for final touch-up.

F. CRYSTAL OSCILLATOR CHASSIS.

The B.N.C. connector labeled 1 MC OUTPUT is the output from the internal 1 mc crystal oscillator and is present at all times.

To adjust the frequency of the 1 mc crystal oscillator a snap-out plug on the left side of the FM-6 case gives access to the trimmer capacitors from the outside.

The preferred method of adjusting the frequency is by comparison to a secondary standard with a Lissajous pattern or using the 1 mc output as a synch for an oscilloscope. An audible beat note type of adjustment will not give the required accuracy. Any one or all of the four trimmer capacitors may be adjusted to stop the oscilloscope pattern.

The crystal oscillator should not be adjusted until after at least a one hour warm up period.

A method of calibrating the 1 mc crystal oscillator to WWV, using a communications receiver is as follows:

Tune the receiver to WWV on either 15 mc or 20 mc. Couple the FM-6 1 mc crystal output (J507 or J702) through a 5-25 $\mu\mu$f trimmer capacitor to the receiver antenna connector. Adjust the trimmer capacitor to get the maximum beat note amplitude as indicated by the S meter. An alternate beat note indicator can be an oscilloscope very slightly coupled (1 or 2 $\mu\mu$f) to the receiver 2 *nd* I.F.

The 1 mc crystal oscillator trimmer capacitors can then be adjusted to the lowest observable beat note frequency.

A beat note frequency of one cycle per second, (timed with a watch) will give a comparison accuracy of 5 parts in 10^8 if the receiver is tuned to 20 mc or 3.75 parts in 10^8 if tuned to 15 mc.

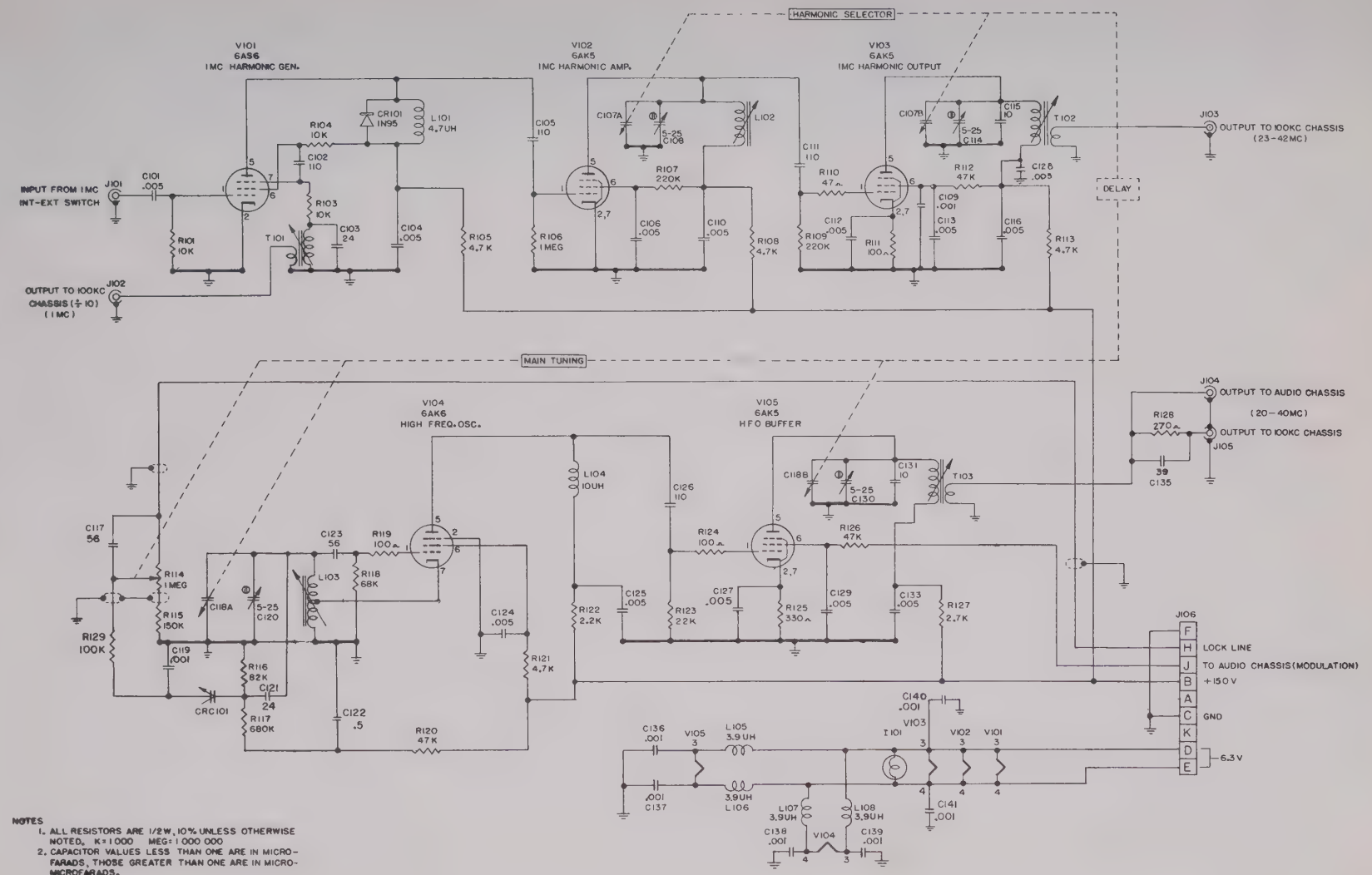


FIG. 4. SCHEMATIC, HIGH FREQUENCY OSCILLATOR AND HARMONIC AMPLIFIER CHASSIS

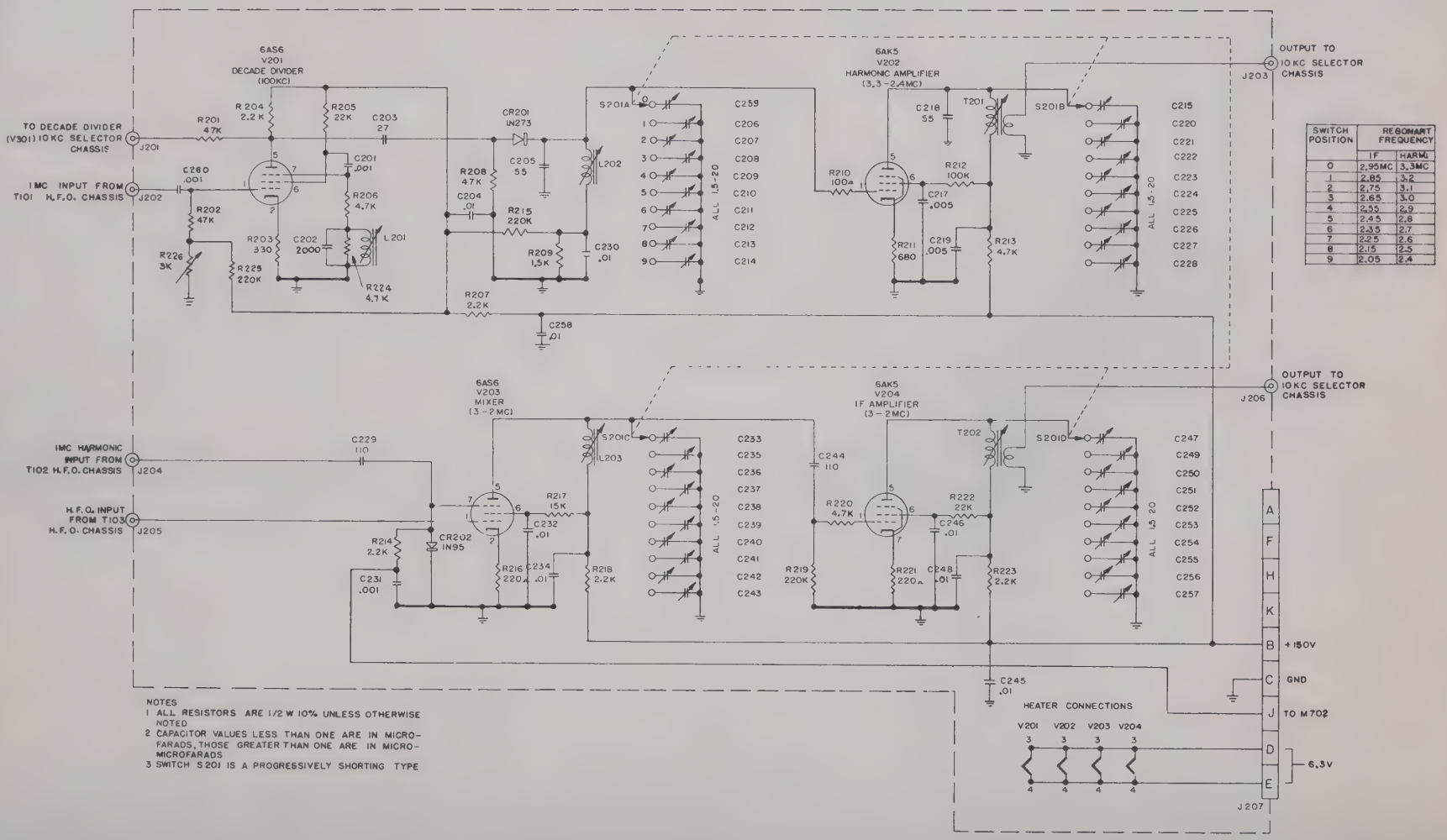


FIG. 5 SCHEMATIC, 100 KC SELECTOR CHASSIS

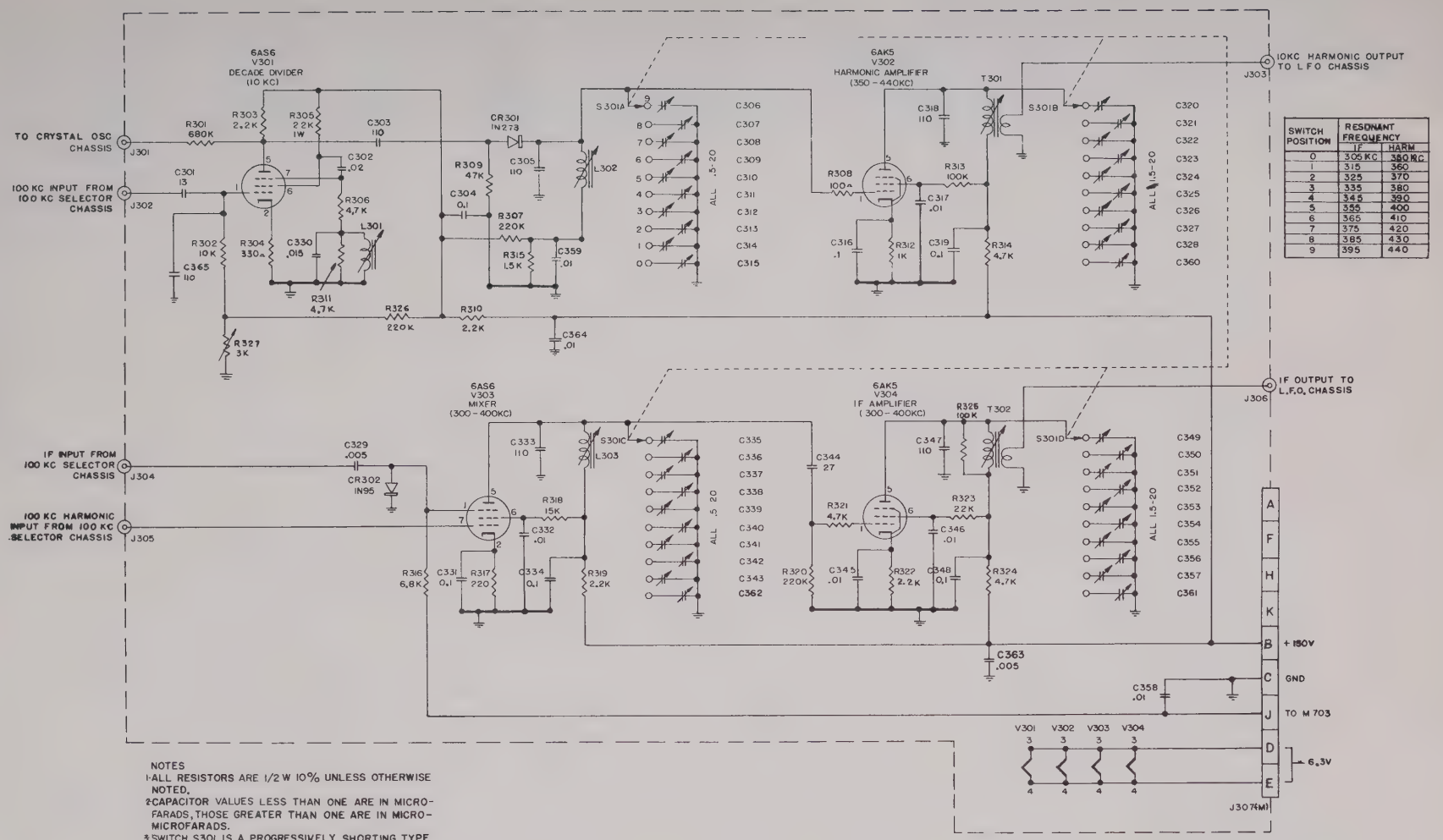


FIG. 6. SCHEMATIC, 10 KC SELECTOR CHASSIS

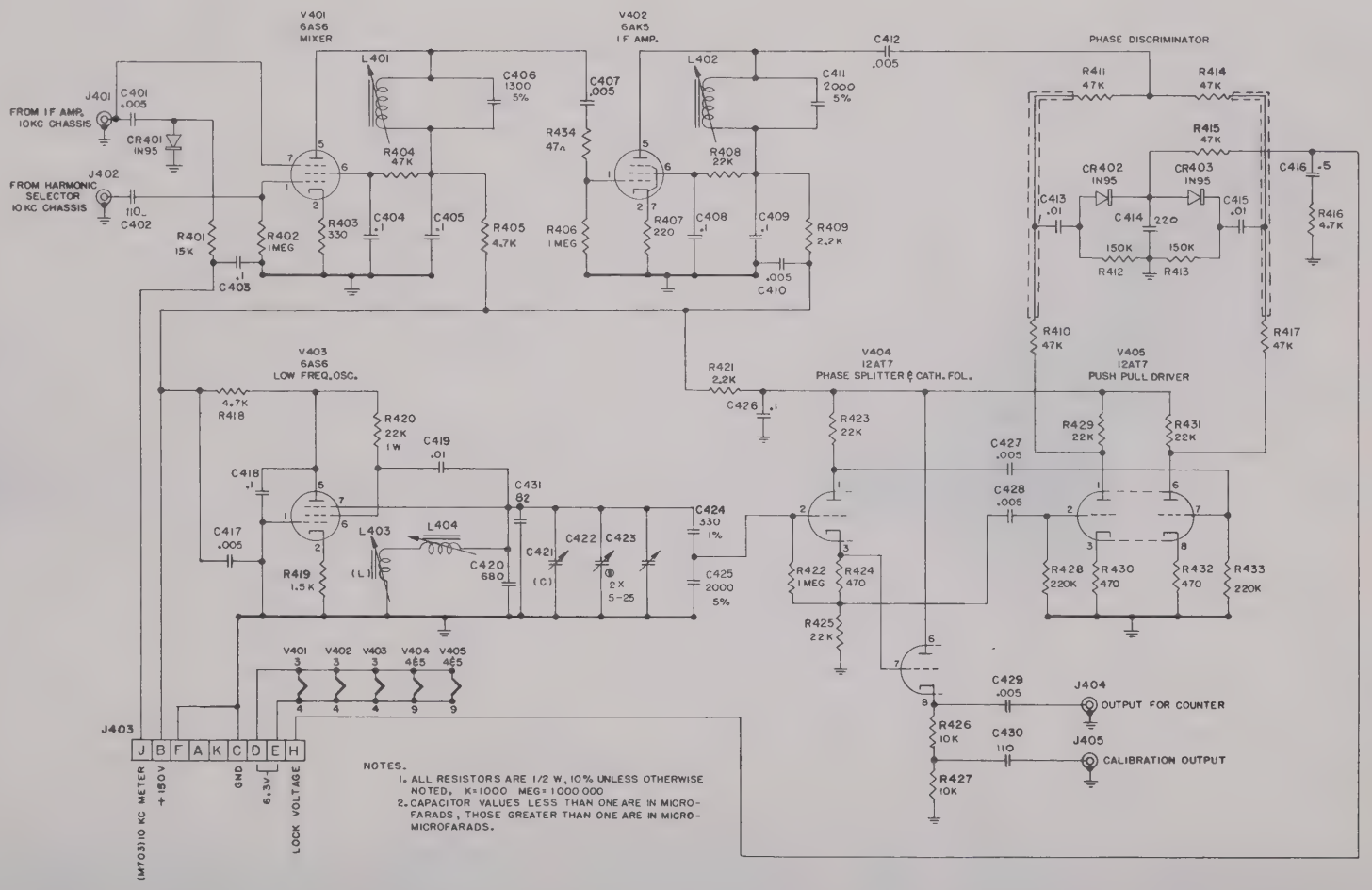


FIG. 7. SCHEMATIC, LOW FREQUENCY OSCILLATOR CHASSIS

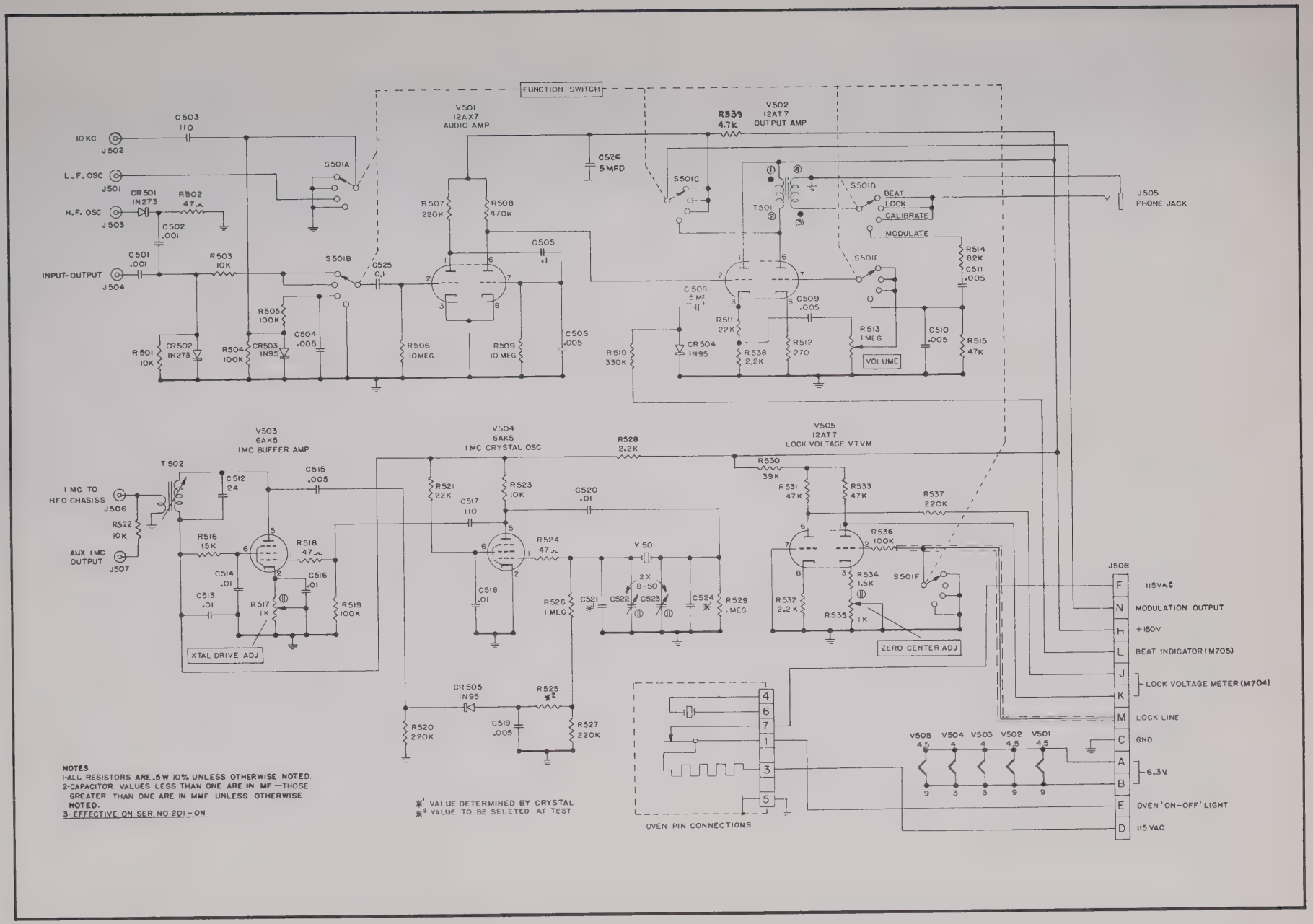
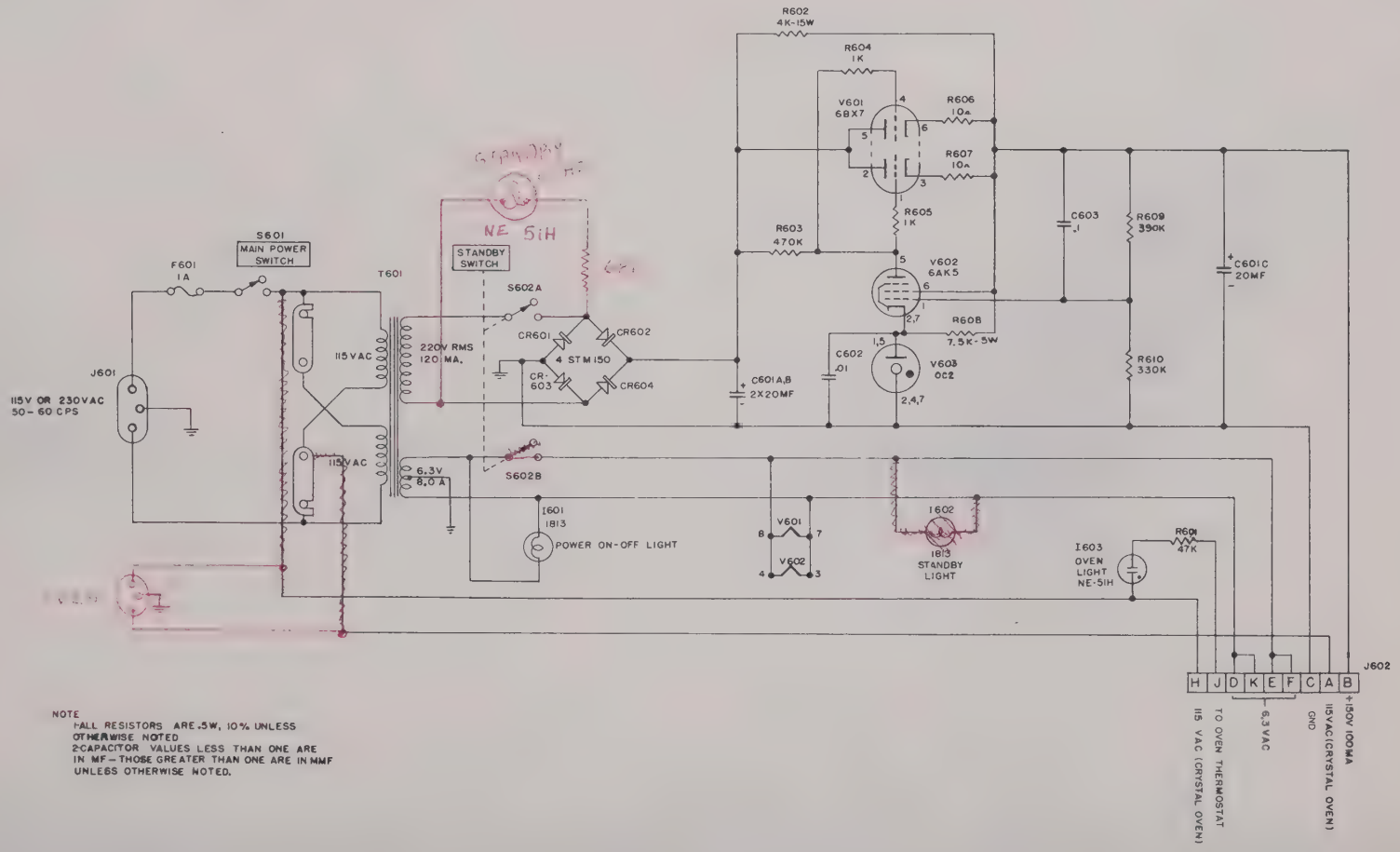


FIG. 8. SCHEMATIC, CRYSTAL OSCILLATOR AND AUDIO CHASSIS



NOTE
ALL RESISTORS ARE .5W, 10% UNLESS OTHERWISE NOTED
2-CAPACITOR VALUES LESS THAN ONE ARE IN MF — THOSE GREATER THAN ONE ARE IN MMF UNLESS OTHERWISE NOTED.

FIG. 9. SCHEMATIC, POWER SUPPLY CHASSIS

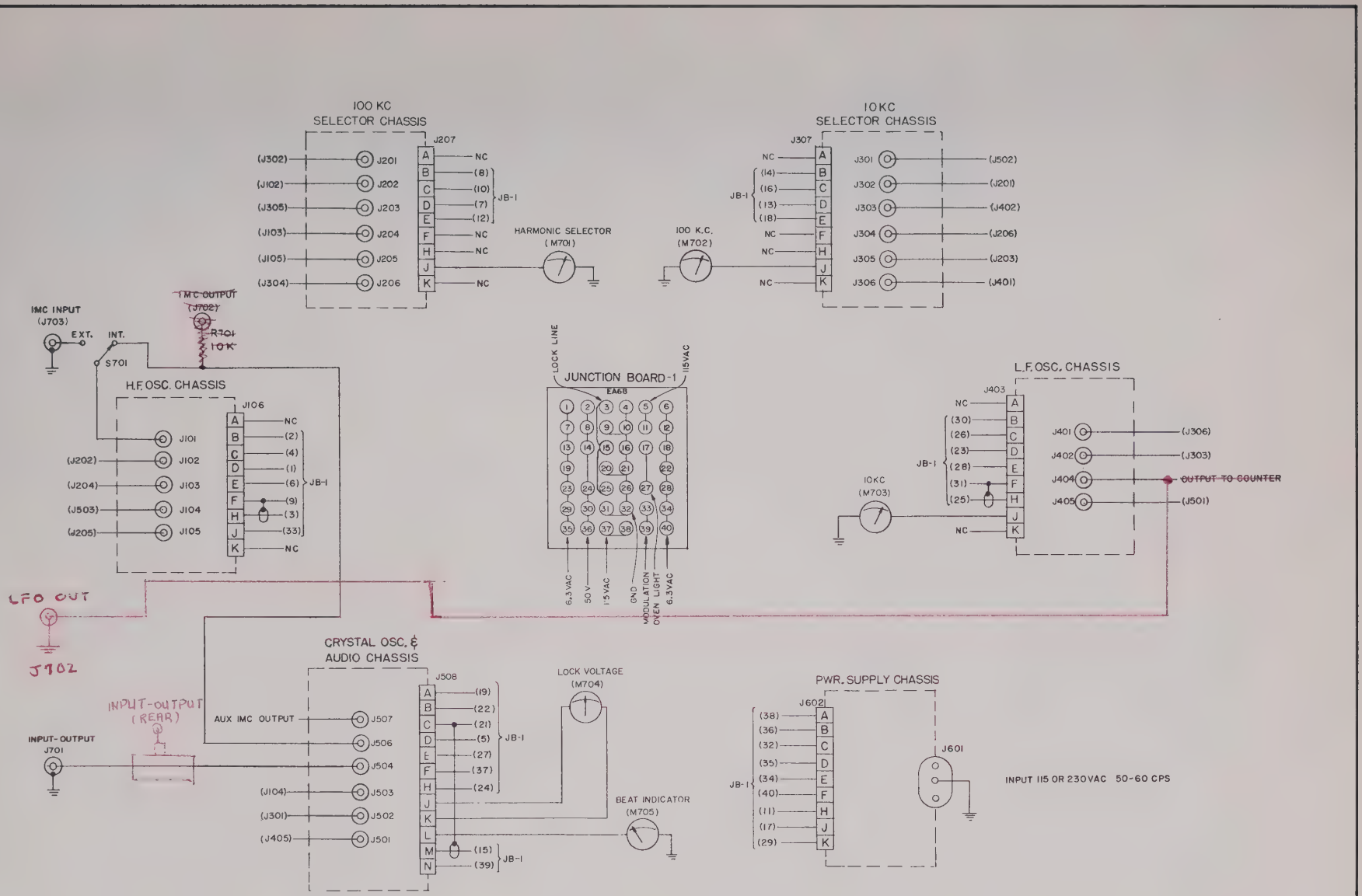


FIG. 10. INTERCONNECTING CABLE BLOCK WIRING DIAGRAM

SECTION V
PARTS LIST

H. F. O. & HARMONIC AMPLIFIER

SYM-BOL	DESCRIPTION	MFR	QTY PER UNIT
C101	Capacitor, fixed, ceramic; .005 mf, 500 VDC	Erie 801-.005	14
C102	Capacitor, fixed, mica; 110 uuf, 500 VDC	Arco CM-15-1-111-J	5
C103	Capacitor, fixed, mica; 24 uuf, 500 VDC	Arco CM-15-1-240-J	1
C104	Same as C101		
C105	Same as C102		
C106	Same as C101		
C107	Capacitor, variable, air gap; 22 uuf - 163 uuf	G. P. I. CA-3	2
C108	Capacitor, variable, 5-25 uuf NPO	Erie 577-06	4
C110	Same as C101		
C111	Same as C102		
C112	Same as C101		
C113	Same as C101		
C114	Same as C108		
C115	Capacitor, fixed, ceramic; 10 uuf, 600 VDC	Erie TCO-10	2
C116	Same as C101		
C117	Same as C123		1
C118	Same as C107		
C119	Capacitor, fixed .001		9
C120	Same as C108		
C121	Same as C102		
C122	Capacitor, fixed .5		1
C123	Capacitor, fixed, mica; 56 uuf, 500 VDC	Arco CM-15-E-560-J	2
C124	Same as C101		
C125	Same as C101		
C126	Same as C102		
C127	Same as C101		
C129	Same as C101		
C130	Same as C108		
C131	Same as C115		
C133	Same as C101		
C135	Capacitor, fixed, ceramic; 39 uuf, 500 VDC	Erie	1
C136	Same as C119		
C137	Same as C119		
C138	Same as C119		
C139	Same as C119		
CRC-101	Capacitor, voltage variable, silicone;	Pacific Semiconductor Vericap V-20	1
CR101	1N95		
C109	Same as C119		
C140	Same as C119		
C141	Same as C119		
C143	Same as C119		
C142	Same as C103		
C128	Same as C101		
J101	Connector, receptacle, electrical 1 pin, female contact	G. P. I. S-PM-1	5
J102	Same as J101		
J103	Same as J101		
J104	Same as J101		
J105	Same as J101		
J106	Connector, receptacle, electrical 9 pin, male contact	Amphenol 126-012	1
L101	Coil, R. F., fixed; 4.7 uh	Millen 6081-4.7	1
L102	Coil, R. F., variable; .25 - .37 uh	G. P. I. LS-25-4	1
L103	Coil, R. F., variable; .35 - .59 uh	G. P. I. LS-25-1	1
L104	Coil, R. F., fixed; 10 uh	Millen 6081-10	1
L105	Coil, R. F., fixed; 3.9 uh	Millen	4
L106	Same as L105		
L107	Same as L105		
L108	Same as L105		
R101	Resistor, fixed, composition; 10,000 ohm, ±10%, ½ W.	Allen Bradley	4
R103	Sames as R101		
R104	Same as R101		
R105	Resistor, composition; 4,700 ohm, ±10%, ½ W.	Allen Bradley	4
R106	Resistor, fixed, composition; 1,000,000 ohm, ±10%, ½ W.	Allen Bradley	1
R107	Resistor, fixed, composition; 220,000 ohm, ±10%, ½ W.	Allen Bradley	3
R108	Same as R105		
R109	Same as R107		
R110	Resistor, fixed, composition; 47 ohm, ±10%, ½ W.	Allen Bradley	1
R111	Resistor, fixed, composition; 100 ohm, ±10%, ½ W.	Allen Bradley	3
R112	Resistor, fixed, composition; 47,000 ohm, ½ W.	Allen Bradley	3
R113	Same as R105		
R114	Resistor, variable, composition; 1,000,000 ohm	Allen Bradley 81636 - Type J	1
R115	Resistor, fixed, composition; 150,000 ohm, ±10%, ½ W.	Allen Bradley	1

SYMBOL	DESCRIPTION	MFR	QTY PER UNIT
R116	Resistor, fixed, composition; 82,000 ohm, ±10%, ½ W.	Allen Bradley	1
R117	Resistor, fixed, composition; 680,000 ohm, ±10%, ½ W.	Allen Bradley	1
R118	Resistor, fixed, composition; 68,000 ohm, ±10%, ½ W.	Allen Bradley	1
R119	Same as R111		
R120	Same as R112		
R121	Same as R105		
R122	Resistor; fixed, composition; 2,200 ohm, ±10%, ½ W.	Allen Bradley	1
R123	Resistor, fixed, composition; 22K ½ W. ±10%		1
R124	Same as R111		
R125	Resistor, fixed, composition; 330 ohm, ±10%, ½ W.	Allen Bradley	1
R126	Same as R112		
R127	Resistor, fixed, composition; 2,700 ohm, ±10%, ½ W.	Allen Bradley	1
R128	Resistor, fixed, composition; 270 ohm, ±10%, ½ W.	Allen Bradley	1
T101	Transformer, tuned; .3 mh - 1 mh	G. P. I. LS-25-3	1
T102	Transformer, tuned; .26 uh - .42 uh	G. P. I. LS-25-5	1
T103	Transformer, tuned; .30 uh - .51 uh	G. P. I. LS-25-2	1
V101	Electron Tube Dual Control R. F. Pentode	6AS6	1
V102	Electron Tube Pentode	6AK5	3
V103	Same as V102		
V104	Electron Tube Pentode	6AK6	1
V105	Same as V102		
X1101	Lamp holder	Dialight 4-1930	
1101	Lamp, Pilot; 6V.	AN3140-328	1
XV101	Socket - Tube; 7 pin, min.	Cinch 53C2476	5
XV102	Same as XV101		
XV103	Same as XV101		
XV104	Same as XV101		
XV105	Same as XV101		
	100 KC CHASSIS		
C201	Same as C231		
C202	Capacitor, fixed, mica; 2000 uuf, 500 VDC	Arco CM-	1
R129	Same as R101		
C203	Capacitor, fixed, ceramic; 27 uuf, 500 VDC	Erie ED-27	1

SYMBOL	DESCRIPTION	MFR	QTY PER UNIT
C204	Capacitor, fixed, ceramic; .01 uf, 500 VDC	Erie 821-.01	8
C205	Capacitor, fixed, mica; 55 uuf, 500 VDC	Arco CM-15-E-550-J	2
C206	Capacitor, trimmer, variable; 1.5 uuf - 20 uuf, NPO	G. P. I. CM-3	4 assem. 10 per assy.
C207	Same as C206		
C208	Same as C206		
C209	Same as C206		
C210	Same as C206		
C211	Same as C206		
C212	Same as C206		
C213	Same as C206		
C214	Same as C206		
C215	Same as C206		
C217	Capacitor, fixed, ceramic; .005 mfd, 500 VDC	Erie 801-.005	2
C218	Same as C205		
C219	Same as C217		
C220	Same as C206		
C221	Same as C206		
C222	Same as C206		
C223	Same as C206		
C224	Same as C206		
C225	Same as C206		
C226	Same as C206		
C227	Same as C206		
C228	Same as C206		
C229	Capacitor, fixed, mica; 110 uuf, ±5%, 500 VDC	Arco CM-15-E-111-J	2
C230	Same as C204		
C231	Capacitor, fixed, ceramic; .001 mf, 500 VDC		3
C232	Sames as C204		
C233	Same as C206		
C234	Same as C206		
C235	Same as C206		
C236	Same as C206		
C237	Same as C206		
C238	Same as C206		
C239	Same as C206		
C240	Same as C206		
C241	Same as C206		
C242	Same as C206		
C243	Same as C206		
C244	Same as C229		
C245	Same as C204		
C246	Same as C204		
C247	Same as C206		
C248	Same as C204		
C249	Same as C206		
C250	Same as C206		
C251	Same as C206		

SYM-BOL	DESCRIPTION	MFR	QTY PER UNIT
C252	Same as C206		
C253	Same as C206		
C254	Same as C206		
C255	Same as C206		
C256	Same as C206		
C257	Same as C206		
C258	Same as C204		
C259	Same as C206		
CR201	Diode, germanium; IN273	Transitron	1
CR202	Diode, germanium; IN95	Hughes	1
J201	Connector, receptacle, electrical 1 pin, female contact	G. P. I. S-PM-1	6
J202	Same as J201		
J203	Same as J201		
J204	Same as J201		
J205	Same as J201		
J206	Same as J201		
J207	Connector, receptacle, electrical 9 pin, male contact	Amphenol	1
L201	Coil, R. F. variable; .8 mh-2.2 mh	G. P. I. LS-25-6	1
L202	Coil, R. F. variable; 12 uh-30 uh	G. P. I. LS-25-7	1
L203	Coil, R. F. variable; 30 uh-100 uh	G. P. I. LS-25-9	1
R201	Resistor, fixed composition; 47,000 ohm, ±10%, ½ W.	Allen Bradley	3
R202	Same as R201		
R203	Resistor, fixed, composition; 330 ohm, ±10%, ½ W.	Allen Bradley	1
R204	Resistor, fixed, composition; 2,200 ohm, ±10%, ½ W.	Allen Bradley	5
R205	Resistor, fixed, composition; 22,000 ohm, ±10%, ½ W.	Allen Bradley	2
R206	Resistor, fixed, composition; 4,700 ohm, ±10%, ½ W.	Allen Bradley	4
R207	Same as R204		
R208	Same as R201		
R209	Resistor, fixed, composition; 1,500 ohm, ±10%, ½ W.	Allen Bradley	1
R210	Resistor, fixed, composition; 10 ohm, ±10%, ½ W.	Allen Bradley	1
R211	Resistor, fixed, composition; 680 ohm, ±10%, ½ W.	Allen Bradley	1
R212	Resistor, fixed, composition; 100,000 ohm, ±10%, ½ W.	Allen Bradley	1
R213	Same as R206		
R214	Same as R204		
R224	Same as R206		
R225	Same as R215		
R226	3K pot	Mel Rain	1
C260	Same as C231		
R215	Resistor, fixed, composition; 220,000 ohm, ±10%, ½ W.	Allen Bradley	3
R216	Resistor, fixed, composition; 220 ohm, ±10%, ½ W.	Allen Bradley	1
R217	Resistor, fixed, composition; 15,000 ohm, ±10%, ½ W.	Allen Bradley	1
R218	Same as R204		
R219	Same as R215		
R220	Same as R206		
R221	Same as R216		
R222	Same as R205		
R223	Same as R204		
S201	Switch, rotary, ceramic; 10 pos., 4X, SP10T	Oak 90351-N4C	1
T201	Transformer, tuned; 12 uh-30 uh	G. P. I. LS-25-8	1
T202	Transformer, tuned; 30 uh-100 uh	G. P. I. LS-25-10	1
V201	Electron Tube Dual Control R-F Pentode	6AS6	2
V202	Electron Tube Pentode	6AK5	2
V203	Same as V201		
V204	Same as V202		
XV101	Socket-Tube; 7 pin min.	Cinch 53C2476	4
XV102	Same as XV101		
XV103	Same as XV101		
XV104	Same as XV101		
	10 KC CHASSIS		
C301	Capacitor, fixed, ceramic; 13 uuh ±10 %	Erie NPOK	1
C302	Capacitor, fixed, ceramic; .02 mfd, 500 VDC	Erie 817-.02	1
C344	Capacitor, fixed, ceramic; 27 uuf, 500 VDC	Erie ED-27	1
C304	Capacitor, fixed, ceramic; .1 mfd, 500 VDC	Erie 827-.1	6
C305	Capacitor, fixed, mica; 110 uuf, ±5%, 500 VDC	Arco CM-15-E-111-J	5
C306	Capacitor, trimmer, variable; 1.5 uuf - 20 uuf NPO	G. P. I. CM-3	4 assem. 10 per assy.
C307	Same as C306		
C308	Same as C306		
C309	Same as C306		
C310	Same as C306		
C311	Same as C306		
C312	Same as C306		

SYM-BOL	DESCRIPTION	MFR	QTY PER UNIT
C313	Same as C306		
C314	Same as C306		
C315	Same as C306		
C316	Same as C304		
C317	Capacitor, fixed, ceramic; .01 mfd, 500 VDC	Erie 821-.01	7
C303	Same as C305		
C318	Same as C305		
C319	Same as C304		
C320	Same as C306		
C321	Same as C306		
C322	Same as C306		
C323	Same as C306		
C324	Same as C306		
C325	Same as C306		
C326	Same as C306		
C327	Same as C306		
C328	Same as C306		
C329	Capacitor, fixed, ceramic; .005 mfd, 500 VDC	Erie 801-.005	2
C330	Capacitor, fixed, Mylar; .015 mfd, 100 VDC	Goodall 663-UW	1
C331	Same as C304		
C332	Same as C317		
C333	Same as C305		
C334	Same as C304		
C335	Same as C306		
C336	Same as C306		
C337	Same as C306		
C338	Same as C306		
C339	Same as C306		
C340	Same as C306		
C341	Same as C306		
C342	Same as C306		
C343	Same as C306		
C345	Same as C317		
C346	Same as C317		
C347	Same as C305		
C348	Same as C304		
C349	Same as C306		
C350	Same as C306		
C351	Same as C306		
C352	Same as C306		
C353	Same as C306		
C354	Same as C306		
C355	Same as C306		
C356	Same as C306		
C357	Same as C306		
C358	Same as C317		
C359	Same as C317		
C360	Same as C306		
C361	Same as C306		
C362	Same as C306		
C363	Same as C329		
C364	Same as C317		
CR301	Diode, germanium; 1N 273	Transitron	1
CR302	Diode, 1N95	Hughes	1
J301	Connector, receptacle, electrical; 1 pin, female contact	G. P. I. S-PM-1	6
J302	Same as J301		
J303	Same as J301		
J304	Same as J301		
J305	Same as J301		
J306	Same as J301		
J307	Connector, receptacle, electrical;	Amphenol 126-012	1
C365	Same as C305		
L301	Coil, R .F. variable; .10 mh - 24 mh	G. P. I. LS-25-17	1
L302	Coil, R. F. variable; .30 mh - 1.1 mh	G. P. I. LS-25-11	1
L303	Coil, R. F. variable; .41 mh - 1.25 mh	G. P. I. LS-25-13	1
R301	Resistor, fixed, composition; 680,000 ohm, ±10%, ½ W.	Allen Bradley	1
R302	Resistor, fixed, composition; 10,000 ohm, ±10%, ½ W.	Allen Bradley	1
R303	Resistor, fixed, composition; 2,200 ohm, ±10%, ½ W.	Allen Bradley	4
R304	Resistor, fixed, composition; 330 ohm, ±10%, ½ W.	Allen Bradley	1
R305	Resistor, fixed composition; 22,000 ohm, ±10%, 1 W.	Allen Bradley	1
R306	Resistor, fixed, composition; 4,700 ohm, ±10%, ½ W.	Allen Bradley	5
R307	Resistor, fixed, composition; 220,000 ohm, ±10%, ½ W.	Allen Bradley	3
R308	Resistor, fixed, composition; 100 ohm, ±10%, ½ W.	Allen Bradley	1
R309	Resistor, fixed, composition; 47,000 ohm, ±10%, ½ W.	Allen Bradley	1
R310	Same as R303		
R312	Resistor, fixed, composition; 1,000 ohm, ±10%, ½ W.	Allen Bradley	1
R313	Resistor, fixed, composition; 100,000 ohm, ±10%, ½ W.	Allen Bradley	2
R314	Same as R306		
R315	Resistor, fixed, composition; 1,500 ohm, ±10%, ½ W.	Allen Bradley	1

SYMBOL	DESCRIPTION	MFR	QTY PER UNIT
R316	Resistor, fixed, composition; 6,800 ohm, ±10%, ½ W.	Allen Bradley	1
R317	Resistor, fixed, composition; 220 ohm, ±10%, ½ W.	Allen Bradley	1
R318	Resistor, fixed, composition; 15,000 ohm, ±10%, ½ W.	Allen Bradley	1
R319	Same as R303		
R320	Same as R307		
R321	Same as R306		
R322	Same as R303		
R323	Same as R303		
R324	Same as R306		
S301	Switch, Rotary, ceramic; 10 pos., 4XSP10T	Oak 92051-N4C	1
R326	Same as R307		
R325	Same as R313		
R311	Same as R306		
R327	3K pot		
T301	Transformer, tuned; .30mh - 1.1 mh	G. P. I. LS-25-12	1
T302	Transformer, tuned; .41 mh - 1.25 mh	G. P. I. LS-25-14	1
V301	Electron Tube Dual Control R-F Pentode	6AS6	2
V302	Electron Tube Pentode	6AK5	2
V303	Same as V101		
V304	Same as V102		
XV301	Socket-Tube; 7 pin, min.	Cinch 53C2476	4
XV302	Same as XV301		
XV303	Same as XV301		
XV304	Same as XV301		
	L. F. O.		
C401	Capacitor, fixed, ceramic; .005 mfd, 500 VDC	Erie 801-.005	7
C402	Capacitor, fixed, mica; 110 uuf, 500 VDC	Arco CM-15-E-111-J	3
C403	Capacitor, fixed, ceramic; .1 mfd, 500 VDC	Erie 827-.1	8
C404	Same as C403		
C405	Same as C403		
C406	Capacitor, fixed, mica; 1300 uuf, 500 VDC	Arco CM-132-J	1
C407	Same as C401		
C408	Same as C403		
C409	Same as C403		
C410	Same as C401		
C411	Same as C425		
C412	Same as C401		
C413	Capacitor, fixed, ceramic; .01 mfd, 500 VDC	Erie 821-.01	3
C414	Capacitor,	Arco CM-15-E-221-J	1
C415	Same as C413		
C416	Capacitor, fixed, ceramic; .5 mfd, 500 VDC		1
C417	Same as C401		
C418	Same as C403		
C419	Same as C413		
C420	Capacitor, 680 uuf, ±5%, - N 750	Centralab TCN-680	1
C421	Capacitor, variable, piston type; .6 uuf - 14 uuf	JFD Electronics VC-11G	1
C422	Capacitor, variable, dual; 2X(5-25 uuf) NPO	Erie 3153-000 5-25 Dual	1
C423	Capacitor, variable, air gap; 33 uuf - 759 uuf	G. P. I. CA-4	1
C424	Capacitor, fixed, mica; 330 uuf, ±1%	Arco CM-15-E-331-F	1
C425	Capacitor, fixed, mica; 2000 uuf, ±5%	Arco CM-20-E-202-J	2
C426	Same as C403		
C427	Same as C401		
C428	Same as C401		
C429	Same as C401		
C430	Same as C402		1
C431	Capacitor, fixed, mica;	Arco CM-15-E-820-J	1
CR401	Diode, germanium; 1N95	Hughes	3
CR402	Same as CR401		
CR403	Same as CR401		
J401	Connector, receptacle, electrical; 1 pin, female contact	G. P. I. ES-PM-1	3
J402	Same as J401		
J403	Connector, receptacle, electrical; 9 pin, male contact	Amphenol 126-012	1
J404	Connector, UG-6040		1
J405	Same as J401		
L401	Coil, R. F. variable; 4.5 mh - 12.5 mh	G. P. I. LS-25-15	3
L402	Same as L401		
L403	Coil, R. F. variable; 126 mh - 250 mh	Miller 4410	1
R401	Resistor, fixed, composition; 10,000 ohm, ±10%, ½ W.	Allen Bradley	2
R402	Resistor, fixed, composition; 1,000,000 ohm, ±10%, ½ W.	Allen Bradley	3
R403	Resistor, fixed, composition; 330 ohm, ±10%, ½ W.	Allen Bradley	1
R404	Resistor, fixed, composition; 47,000 ohm, ±10%, ½ W.	Allen Bradley	5
R405	Resistor, fixed, composition; 4700 ohm, ±10%, ½ W.	Allen Bradley	3
R406	Same as R402		

SYMBOL	DESCRIPTION	MFR	QTY PER UNIT
R407	Resistor, fixed, composition; 220 ohm, ±10%, ½ W.	Allen Bradley	1
R408	Resistor, fixed, composition; 22,000 ohm, ±10%, ½ W.	Allen Bradley	6
R409	Resistor, fixed, composition; 2200 ohm, ±10%, ½ W.	Allen Bradley	2
R410	Same as R404		
R411	Same as R404		
R412	Resistor, fixed, composition; 150,000 ohm, ±10%, ½ W.	Allen Bradley	2
R413	Same as R412		
R414	Same as R404		
R415	Same as R404		
R416	Same as R405		
R417	Same as R404		
R418	Same as R405		
R419	Resistor, fixed, composition; 1500 ohm, ±10%, ½ W.	Allen Bradley	1
R420	Resistor, fixed, composition; 22K 1 W. ±10%		1
R421	Same as R409		
R422	Same as R402		
R401	Resistor, fixed, composition; 15K ±10%, ½ W.		
R423	Same as R408		
R424	Resistor, fixed, composition; 470 ohm, ±10%, ½ W.	Allen Bradley	3
R425	Same as R408		
R426	Same as R401		
R427	Same as R401		
R428	Resistor, fixed, composition; 220,000 ohm, ±10%, ½ W.	Allen Bradley	2
R429	Same as R408		
R430	Same as R424		
R431	Same as R408		
R432	Same as R424		
R433	Same as R428		
R434	Resistor, fixed, composition; 47 ohm, ±10%, ½ W.	Allen Bradley	1
V401	Electron Tube Dual Control R-F Pentode	6AS6	2
V402	Electron Tube Pentode	6AK5	1
V403	Same as V401		
V404	Electron Tube Dual Triode	12AT7	2
V405	Same as V404		
XV401	Socket - Tube; 7 pin, min.	Cinch	3
XV402	Same as XV401	53C24761	
XV403	Same as XV401		
XV404	Socket - Tube; 9 pin, min.	Cinch 44F24760	2
XV405	Same as XV404		

CRYSTAL OSCILLATOR & AUDIO AMPLIFIER CHASSIS

SYMBOL	DESCRIPTION	MFR	QTY PER UNIT
C501	Capacitor, fixed, ceramic; .001 uf, 500 VDC	Erie 801-.001	2
C502	Same as C501		
C503	Capacitor, fixed, ceramic; .005 uf, 500 VDC	Erie 801-.005	8
C504	Same as C503		
C505	Capacitor, fixed, ceramic; .1 uf, 500 VDC	Erie 827-.1	2
C506	Same as C503		
C508	Capacitor, fixed, electrolytic; 5 uf, 150 VDC	Aerovox E26650	1
C509	Same as C503		
C510	Same as C503		
C511	Same as C503		
C512	Capacitor, fixed, mica; 24 uuf ±5%, 500 VDCW	Arco CM-15-E-240-J	1
C513	Same as C505		
C514	Capacitor, fixed, ceramic; .01 mfd, 500 VDC	Erie 821-.01	5
C515	Same as C503		
C516	Same as C514		
C517	Capacitor, fixed, mica; 110 uuf, ±5%, 500 VDCW	Arco CM-15-E-111-J	1
C518	Same as C514		
C519	Same as C504		
C520	Same as C514		
C521	Capacitor, molded mica; Selected value	Arco Type DM-15	2
C522	Capacitor, variable, ceramic; 2 (8-50) uuf, 500 VDCW	Erie	2
C523	Same as C522		
C524	Same as C521		
C525	Same as C505		
CR501	Diode, germanium;1N273	Transitron	2
CR502	Same as CR501		
CR503	Diode, germanium; 1N95	Hughes	3
CR504	Same as CR503		
CR505	Same as CR503		
J501	Connector, receptacle, electrical; 1 pin, male contact	G. P. I. S-PM-1	5
J502	Same as J501		
J503	Same as J501		
J504	Same as J501		
J505	Connector, receptacle, electrical; 1 pin, female contact	Switchcraft 11	1
J506	Same as J501		

SYM-BOL	DESCRIPTION	MFR	QTY PER UNIT
J507	Connector, receptacle, electrical, BNC-female contact (UG-657/U)	Amphenol 31-102	1
J508	Connector, receptacle, electrical; 12 pin, female contact	Winchester M12P-LS12N	1
R501	Resistor, fixed, composition; 10,000 ohm, ±10%, ½ W.	Ohmite	4
R502	Resistor, fixed, composition; 47 ohm, ±10%, ½ W.	Ohmite	3
R503	Same as R501		
R504	Resistor, fixed, composition; 100 K ±10%, ½ W.	Ohmite	4
R505	Same as R504		
R506	Resistor, fixed, composition; 10,000.000 ohm, ±10%, ½ W.	Ohmite	2
R507	Resistor, fixed, composition; 220,000 ohm, ±10%, ½ W.	Ohmite	4
R508	Resistor, fixed, composition; 470,000 ohm, ±10%, ½ W.	Ohmite	1
R509	Same as R506		
R510	Resistor, fixed, composition; 330,000 ohm, ±10%, ½ W.	Ohmite	1
R511	Resistor, fixed, composition; 22,000 ohm, ±10%, ½ W.	Ohmite	2
R512	Resistor, fixed, composition; 270 ohm, ±10%, ½ W.	Ohmite	1
R513	Resistor, variable, composition; 1,000,000 ohm	Ohmite CA-1052 AB	1
R514	Resistor, fixed, composition; 82,000 ohm, ±10%, ½ W.	Ohmite	1
R515	Resistor, fixed, composition; 47,000 ohm, ±10%, ½ W.	Ohmite	3
R516	Resistor, fixed, composition; 15,000 ohm, ±10%, ½ W.	Ohmite	1
R517	Resistor, variable, wire wound; 1,000 ohm,	Mel-Rain	2
R518	Same as R502		
R519	Same as R504		
R520	Same as R507		
R521	Same as R511		
R523	Same as R501		
R524	Same as R502		
R525	Resistor, fixed, composition; Selected value, ±10%, ½ W.	Ohmite	1
R526	Resistor, fixed, composition; 1,000,000 ohm, ±10%, ½ W.	Ohmite	2
R527	Same as R507		
R528	Resistor, fixed, composition; 2,200 ohm, ±10%, ½ W.	Ohmite	3
R529	Same as R526		
R530	Resistor, fixed, composition; 39,000 ohm, ±10%, ½ W.	Ohmite	1
R531	Same as R515		
R532	Same as R528		
R533	Same as R515		
R534	Resistor, fixed, composition; 1,500 ohm, ±10%, ½ W.	Ohmite 1	1
R535	Same as R517		
R536	Same as R504		
R537	Same as R507		
R538	Same as R528		
S501	Switch, Rotary, wafer, 6X 4PST	G. P. I. SW-14	1
T501	Transformer, audio output; Pri Z 6.500 ohm - Sec. Z 600 ohm	Triad 45266	1
T502	Transformer, tuned; .30 mh - 1 mh	G. P. I. LS-25-16	1
V501	Electron Tube; Dual Triode	12AX7	1
V502	Electron Tube; Dual Triode	12AT7	2
V503	Electron Tube; Pentode	6AK5	2
V504	Same as V503		
V505	Same as V502		
R539	Resistor, fixed, composition; 4700 ohm		1
R522	Same as R501		1
XV501	Socket - Tube; 9 pin, min.	Cinch 44F24760	3
XV502	Same as XV501		
XV503	Socket - Tube; 7 pin, min.	Cinch 53 C24761	2
XV504	Same as XV503		
XV505	Same as XV501		
XY501	Socket - Tube; Octal	Cinch 16759	1
Y501	Crystal & oven assembly; 1 M.C.	G. P, I, YC-3	1
	POWER SUPPLY		
C601	Capacitor, fixed, electrolytic; 3 x 20 mfd, 450 VDCW	Aerovox AEP 444J	1
C602	Capacitor, fixed, ceramic; .1 mf, 500 VDC	Erie 821-.01	1
C603	Capacitor, fixed, ceramic; .1 mf, 500 VDC	Erie 827.1	1

SYM-BOL	DESCRIPTION	MFR	QTY PER UNIT
CR601	Diode, silicon	Sarkes-Tarzian M150	
CR602	Same as CR601		
CR603	Same as CR601		
CR604	Same as CR601		
J601	Receptacle - Power	Tower H1061	1
J602	Connector, female, 9 pin	Amphenol 26-219	1
R601	Resistor, fixed, composition; 47,000 ohm, ±10%, ½ W.	Ohmite	1
R602	Resistor, fixed, wire wound; 4,000 ohm, 15 W.	Tru-Ohm	1
R603	Resistor, fixed, composition; 470,000 ohm, ±10%, ½ W.	Ohmite	1
R604	Resistor, fixed, composition; 1,000 ohm, ±10%, ½ W.	Ohmite	2
R605	Same as R604		
R606	Resistor, fixed, composition; 10 ohm, ±10%, ½ W.	Ohmite	2
R607	Same as R606		
R608	Resistor, fixed, composition; 7500 ohm, 5 W.	Ward Leonard Axiohm Type 5X	1
R610	Resistor, fixed, composition; 330,000 ohm, ±10%, ½ W.	Ohmite	1
R609	Resistor, fixed, composition; 390K ±10%, ½ W.		1
S601	Switch - Toggle; SPDT	Carling 112-73	
S602 A-B	Switch - Toggle; DPDT	Carling 2-BL62-73	
R620	Resistor, fixed, composition; 10,000 ohm, ±10%, ½ W.		1
T601	Transformer - Power Pri: 115/220 V. 50 - 60 cps Sec: 220 V at .120 A. 6.3 VCT at 8. A.	Triad 66612	
V601	Electron Tube, Dual Triode	6BX7	1
V602	Electron Tube, Pentode	6AK5	1
V603	Electron Tube, V.R. Tube	OC2	1
XV601	Socket Tube; Octal	Cinch 16758	2
XV602	Socket Tube; 7 pin	Cinch 53C24761	2
XV603	Same as XV602		
XC601	Same as XV601		
X1601	Indicator light assembly	Marco VM312-6	3
X1602	Same as X1601		
X1603	Same as X1601		
1601	Indicator light; 6 V.	G. E. 1813	2
1602	Same as 1601		
1603	Indicator light - Neon	G. E. NE51	1
	FRONT PANEL		
J701	Connector, receptacle, electrical, BNC - Female contact UG-492A/U	Amphenol 31-220	1
J702	Connector, receptacle, electrical, BNC Female contact UG-657/U	Amphenol 31-102	2
J703	Same as J702		
M701	Meter 0 - 100 uA	G. P. I. ME-5 Tune for max.	3
M702	Same as M701		
M703	Same as M701		
M704	Meter 100 uA - 0 - 100 uA	G. P. I. ME-6 zero center	1
M705	Meter 0 - 100 uA	ME-5 Tune for min.	1
S701	Switch - Toggle SPDT	Carling AB-252-71	1
	Panel Front	G. P. I. AP-56	1
W701	Cable-Harness; interconnecting complete with plugs	G. P. I. DI-153	1
W702	Power Cord, cable with plugs, 3 conductor	Belden KH-3385	1
WP702	Plug Adaptor 3 pin to 2 pin and ground wire	Cornish 228	1
Knob	Medium - Plain harmonic selector	Johnson 116-220-2	
Knob	Medium - Dot audio gain	Johnson 116-224-2	
Knob	Medium - Dot selector switch	Johnson 116-224-2	
Knob	Large Crank L. F. O. Tuning	Johnson 116-226-2	
Knob	Large Crank H. F. O. Tuning	Johnson 116-226-2	
Knob	Bar Type 100 K. C. selector	G. P. I. OP-1	
Knob	Bar Type 10 K. C. selector	G. P. I. OP-1	
Knob	Small "At 0" Tuning	Harry Davies 1450	
Knob	Small "At 10" Tuning	Harry Davies 1450	

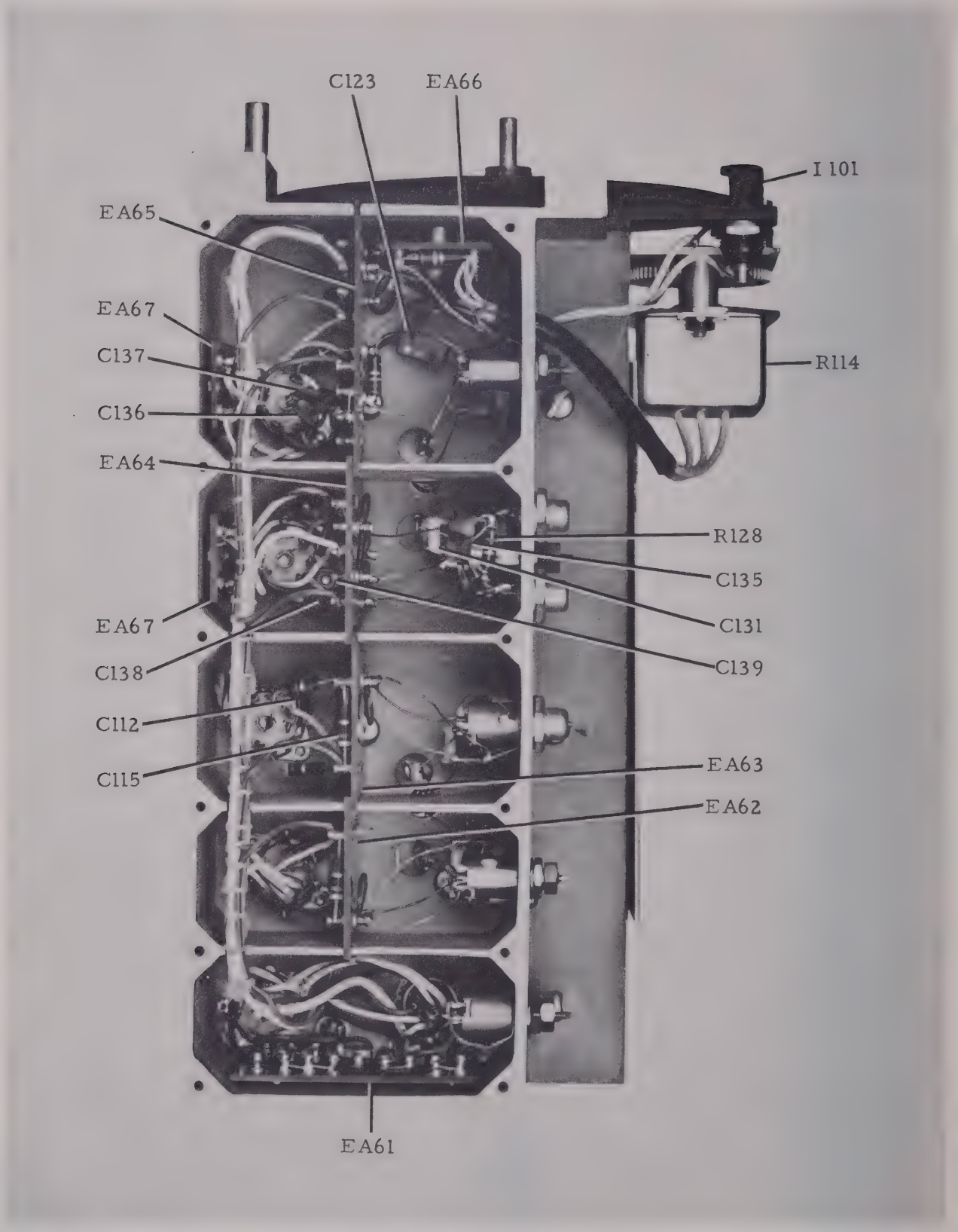


FIG. 11. PARTS LOCATION, HIGH FREQUENCY OSCILLATOR AND HARMONIC AMPLIFIER CHASSIS

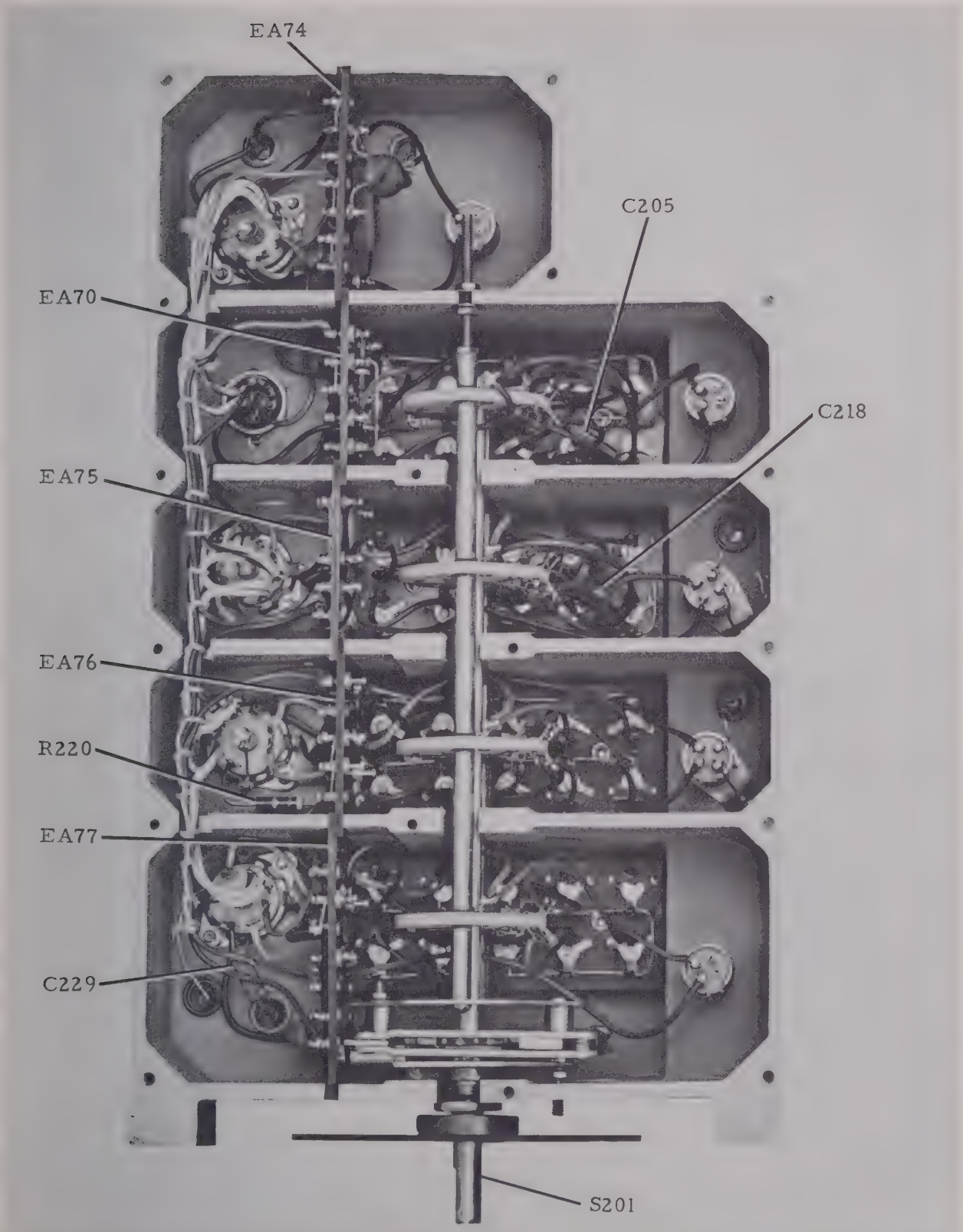


FIG. 12. PARTS LOCATION, 100 KC SELECTOR CHASSIS

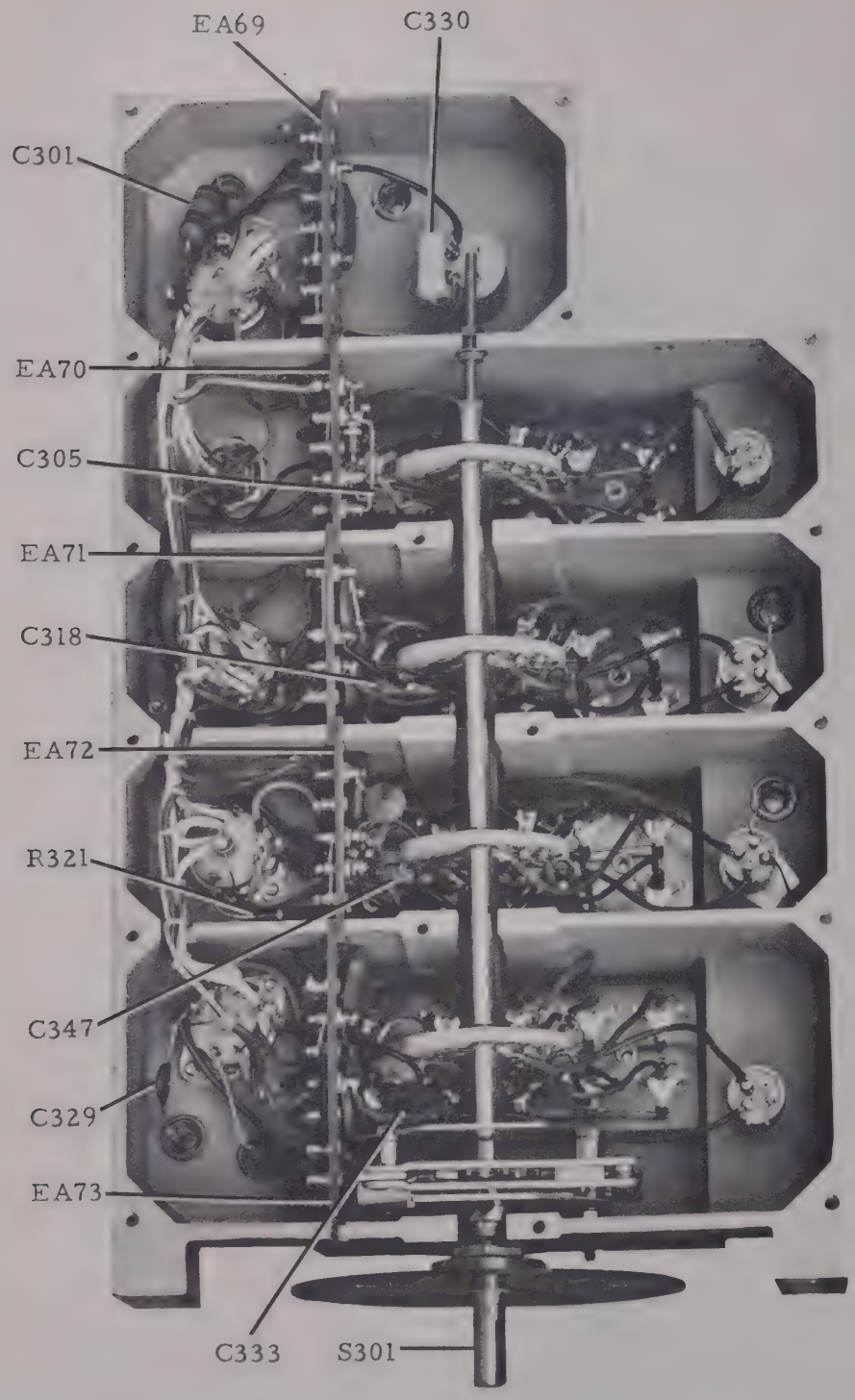


FIG. 13. PARTS LOCATION, 10 KC SELECTOR CHASSIS

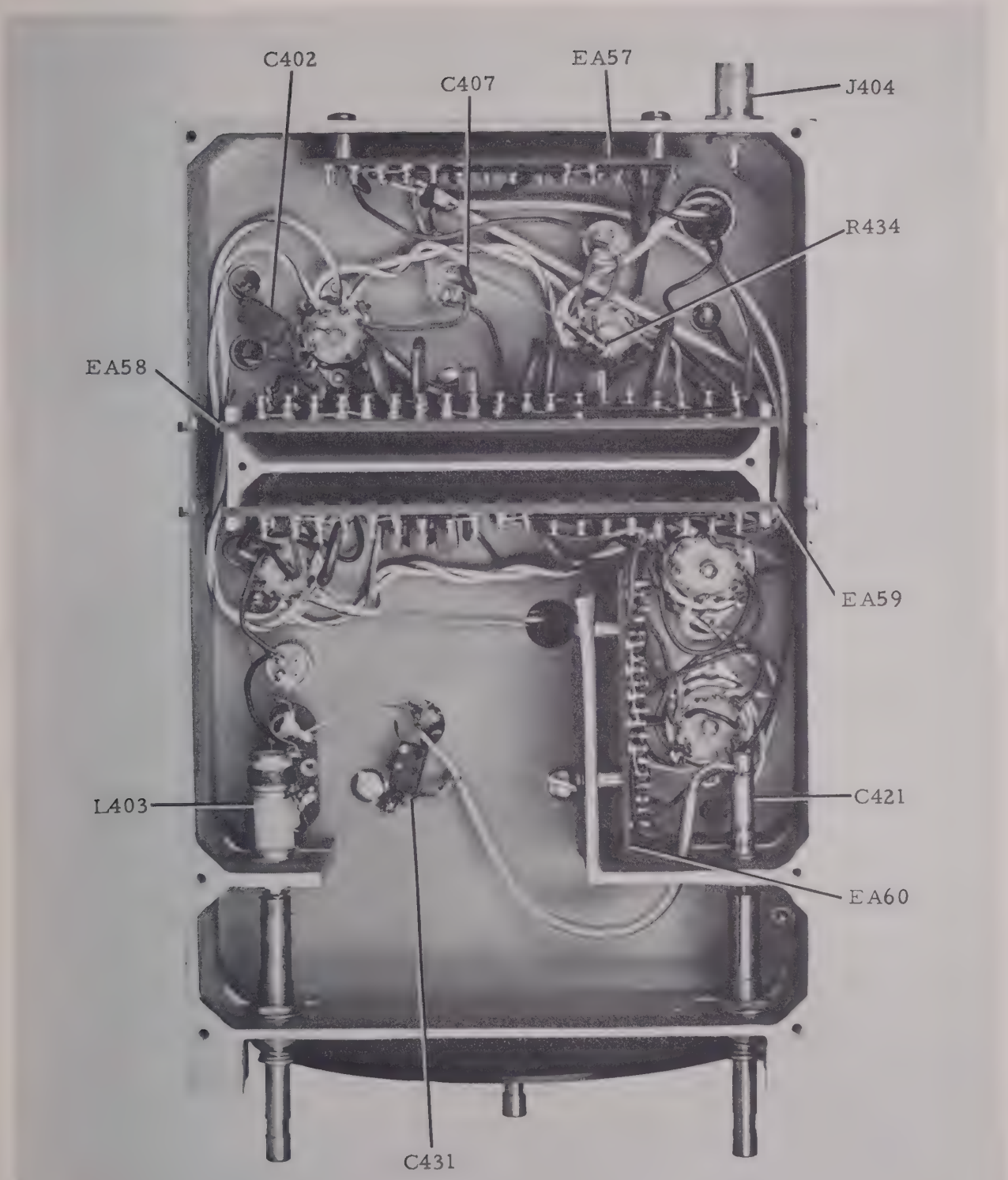


FIG. 14. PARTS LOCATION, LOW FREQUENCY OSCILLATOR

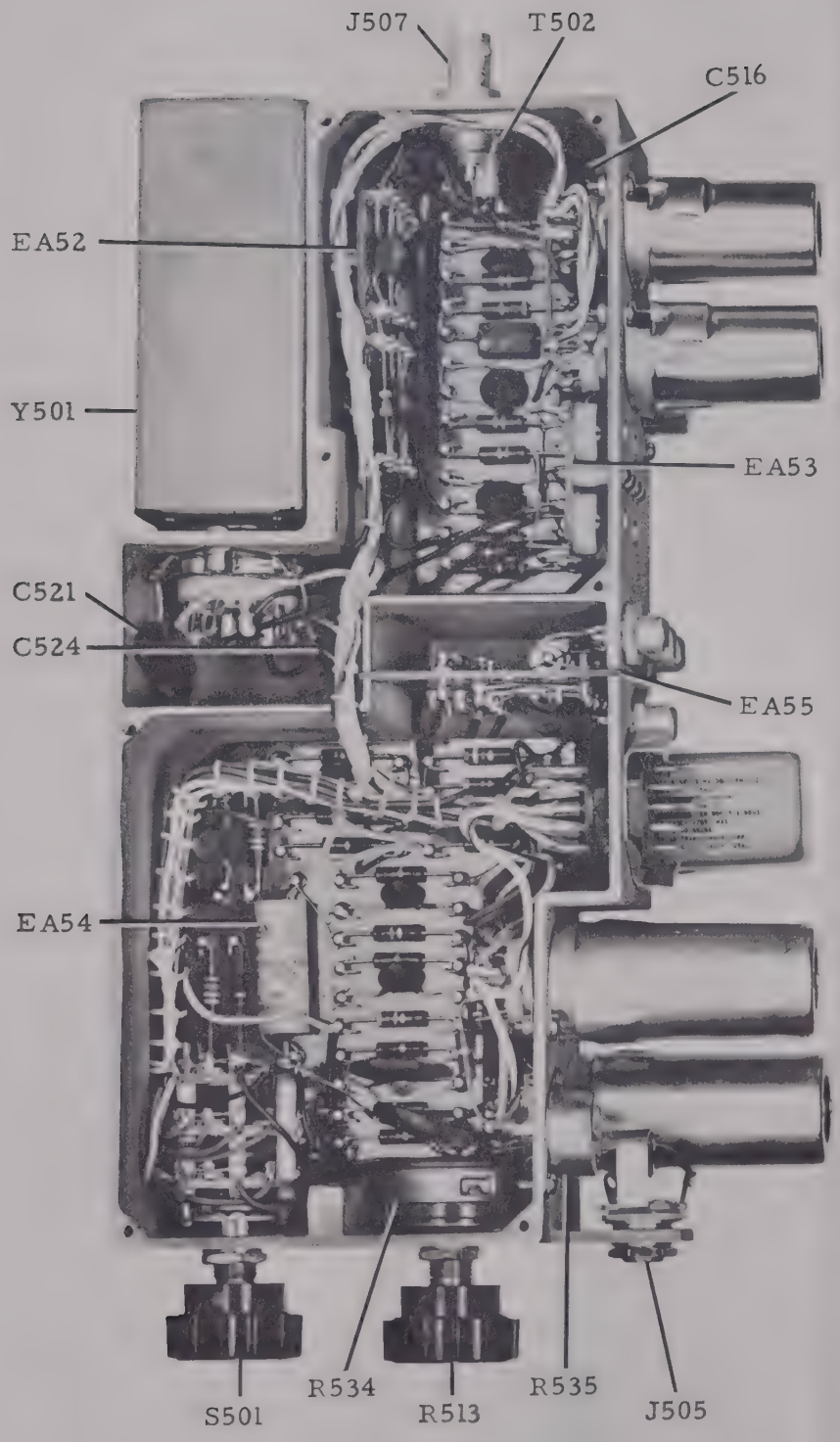


FIG. 15. PARTS LOCATION, CRYSTAL OSCILLATOR

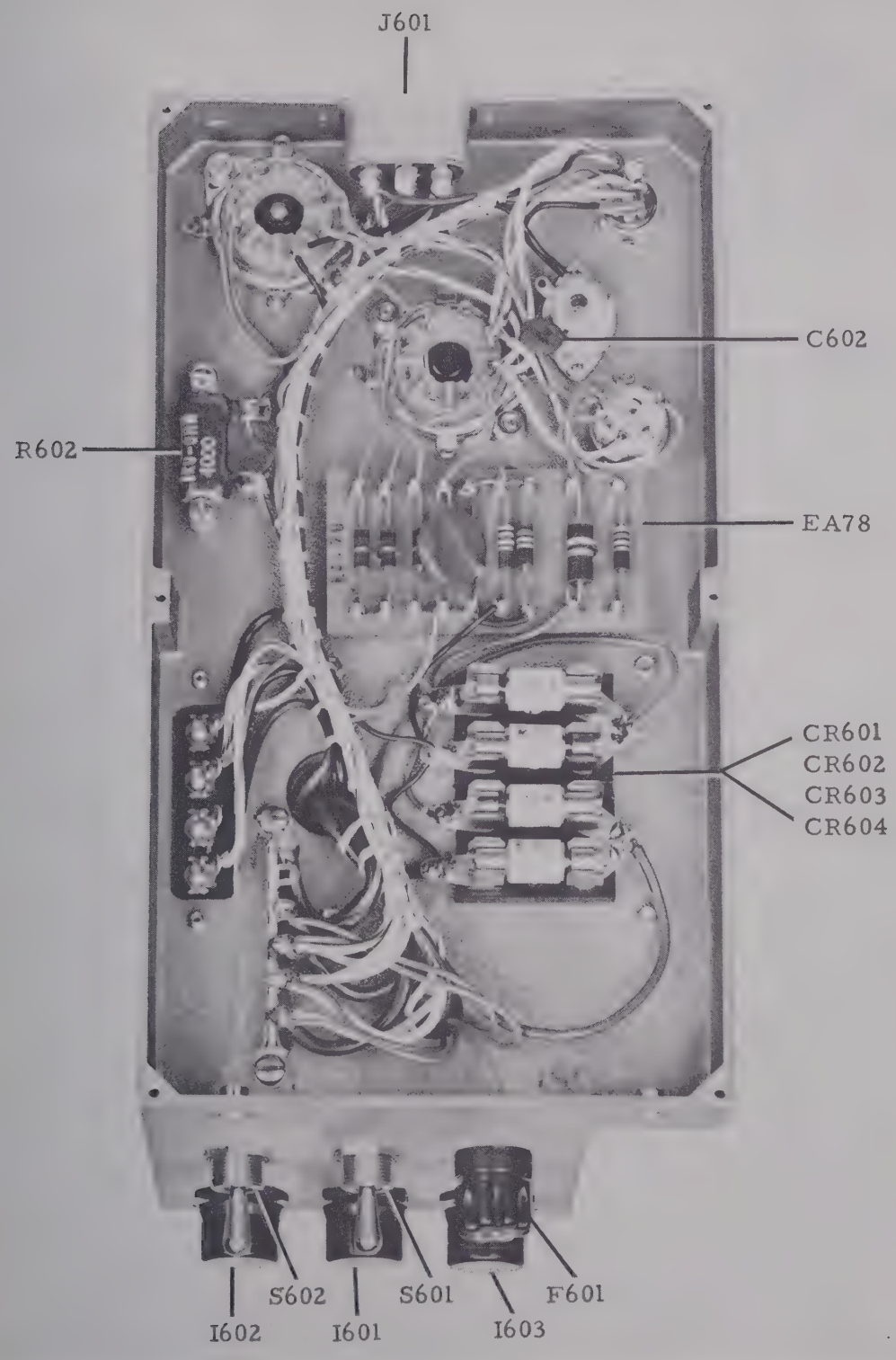


FIG. 16. PARTS LOCATION, POWER SUPPLY

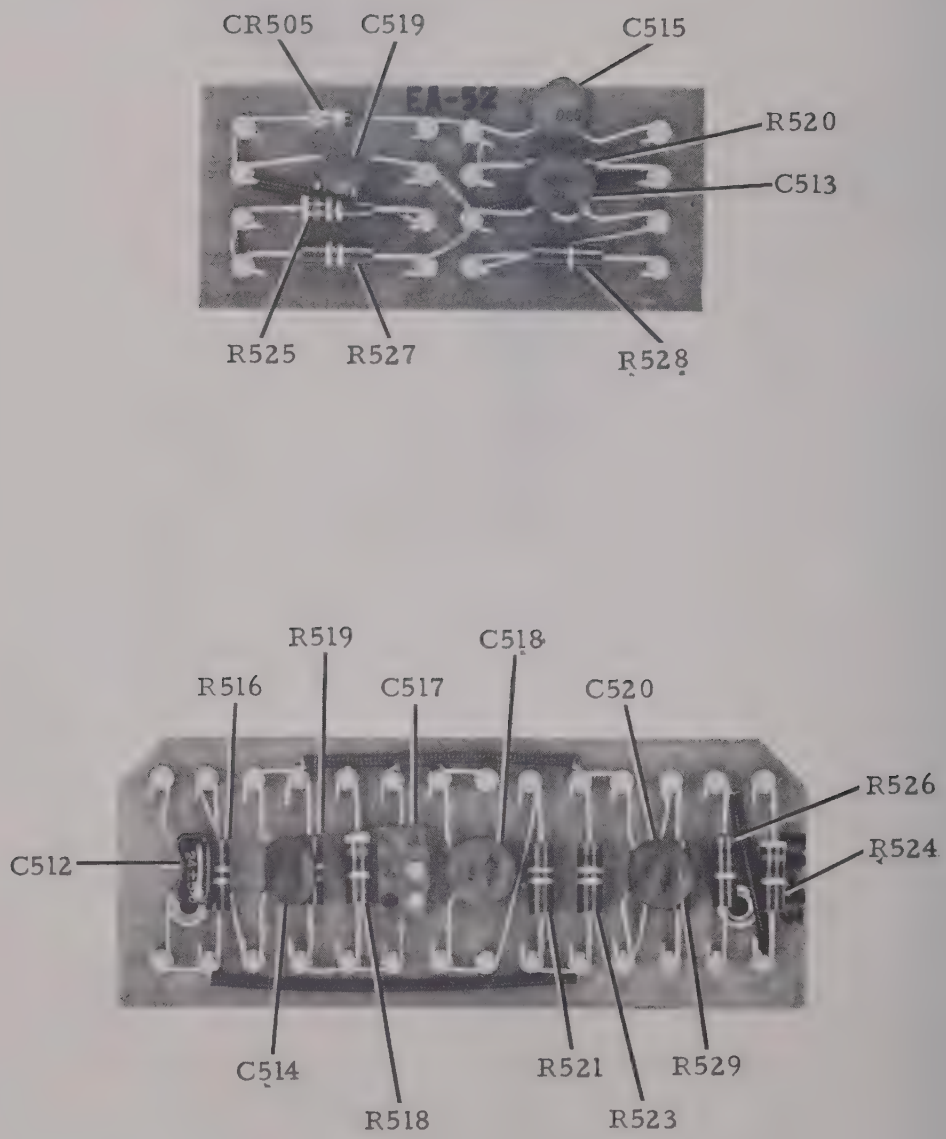


FIG. 17. BOARD ASSEMBLY EA52, EA53

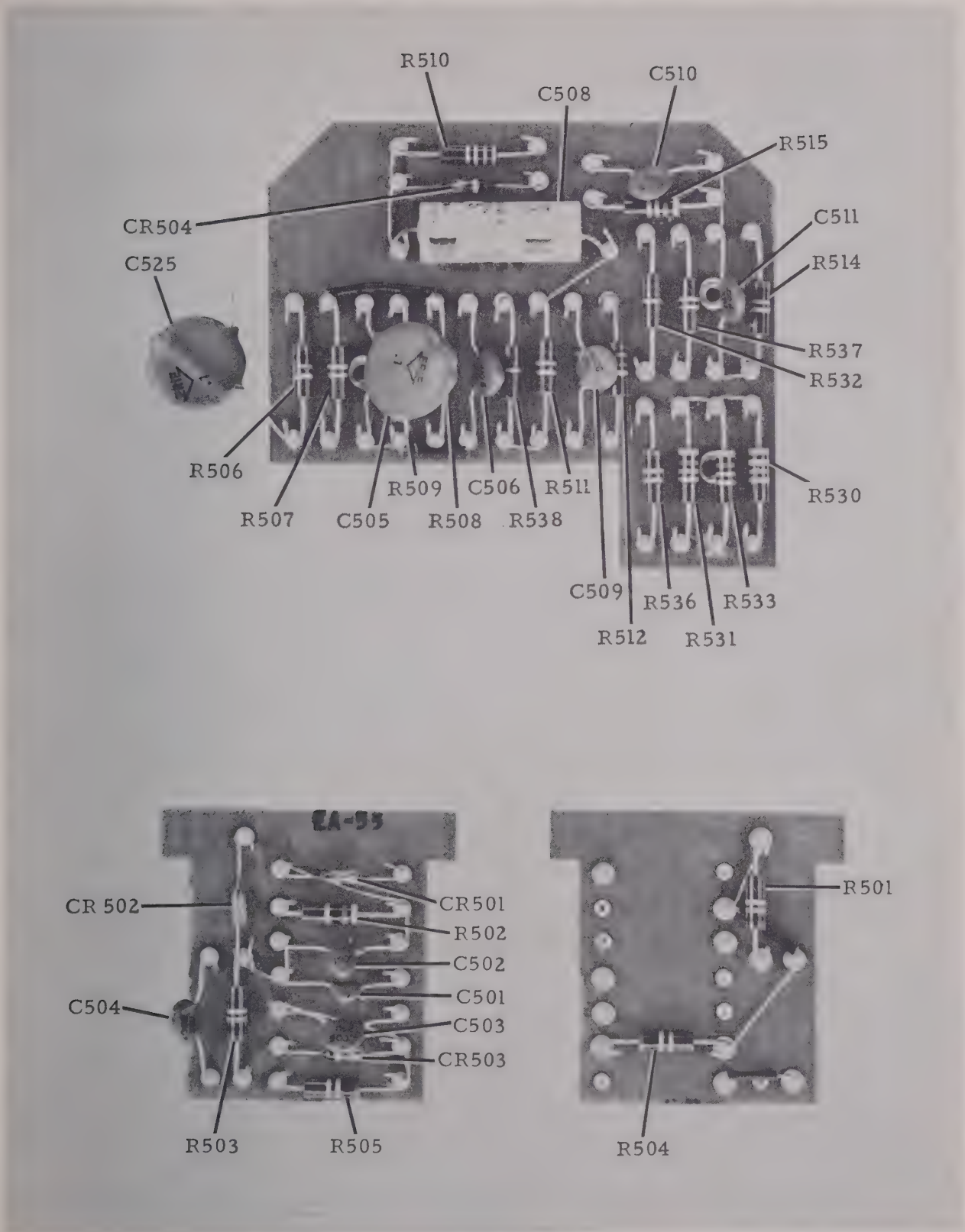


FIG. 18. BOARD ASSEMBLY EA54, EA55

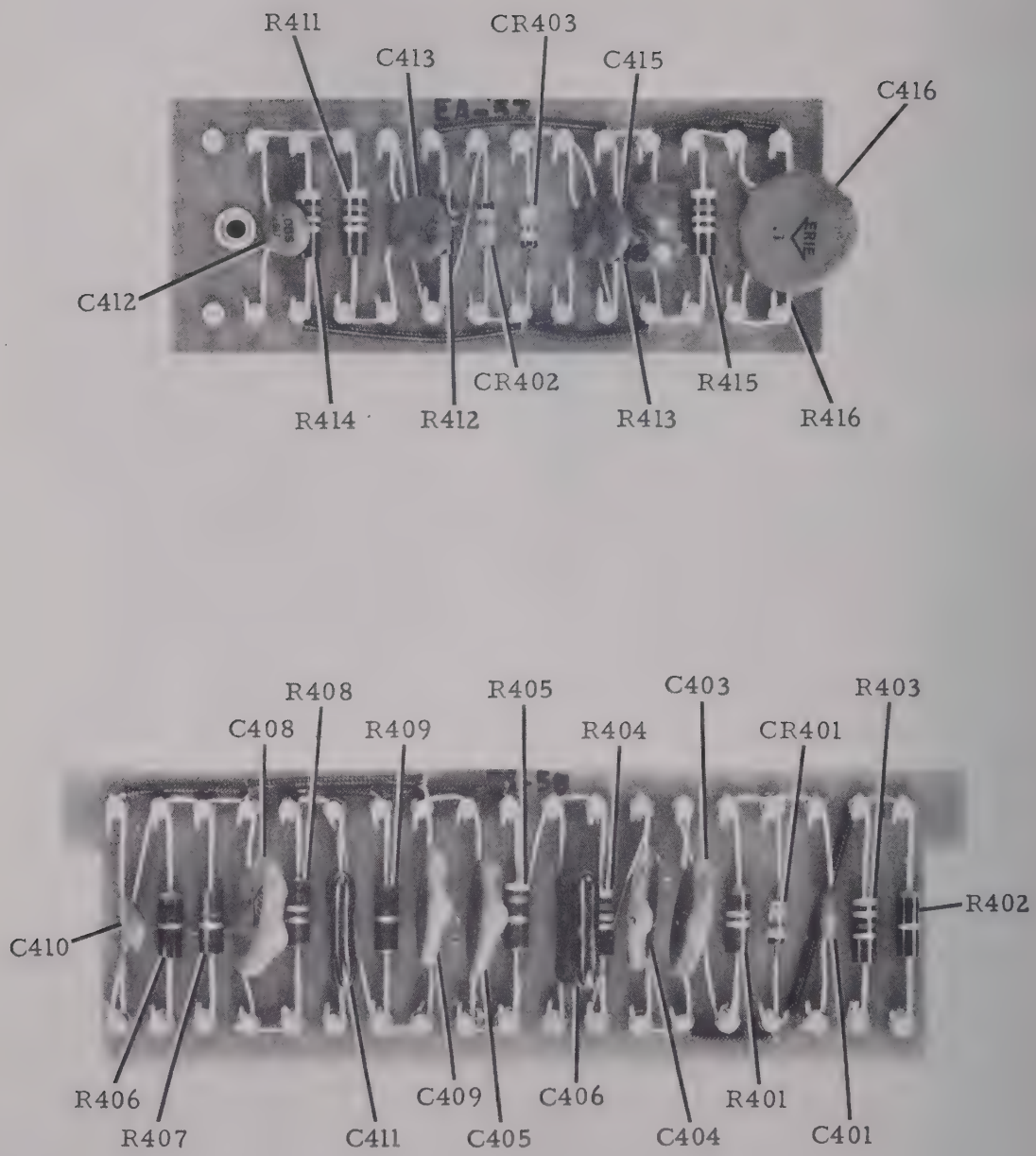


FIG. 19. BOARD ASSEMBLY EA57, EA58

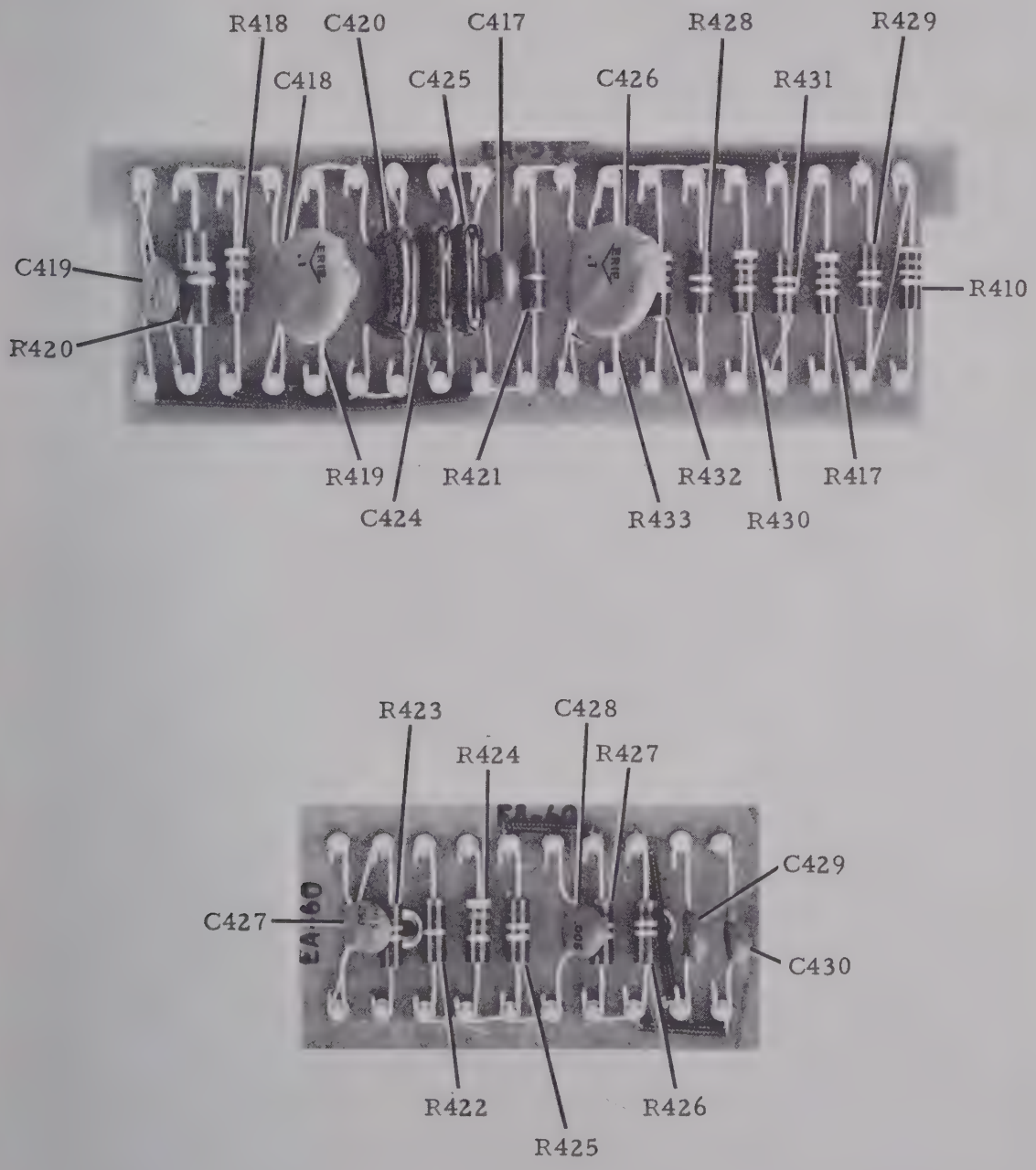


FIG. 20. BOARD ASSEMBLY EA59, EA60

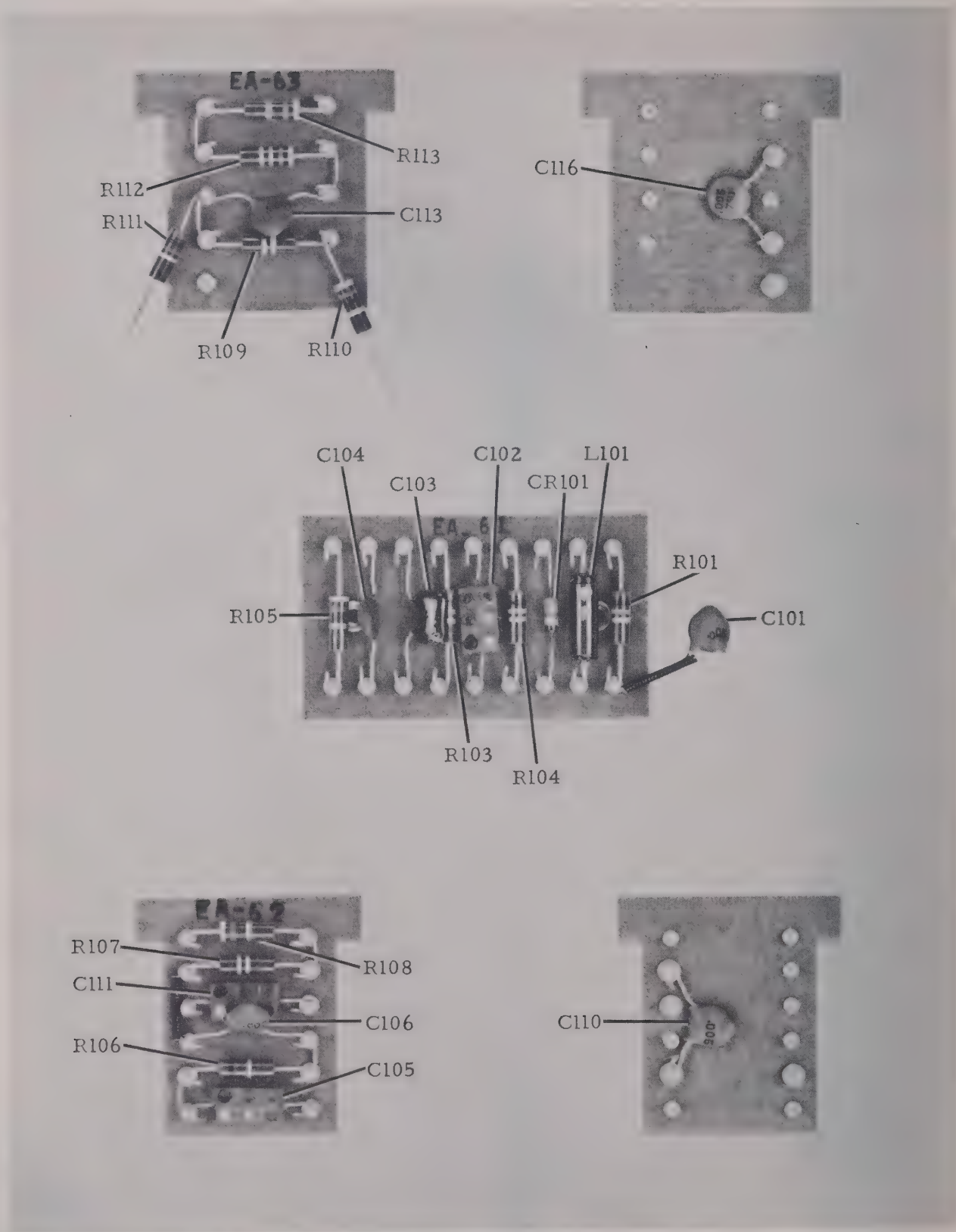


FIG. 21. BOARD ASSEMBLY EA61, EA62, EA63

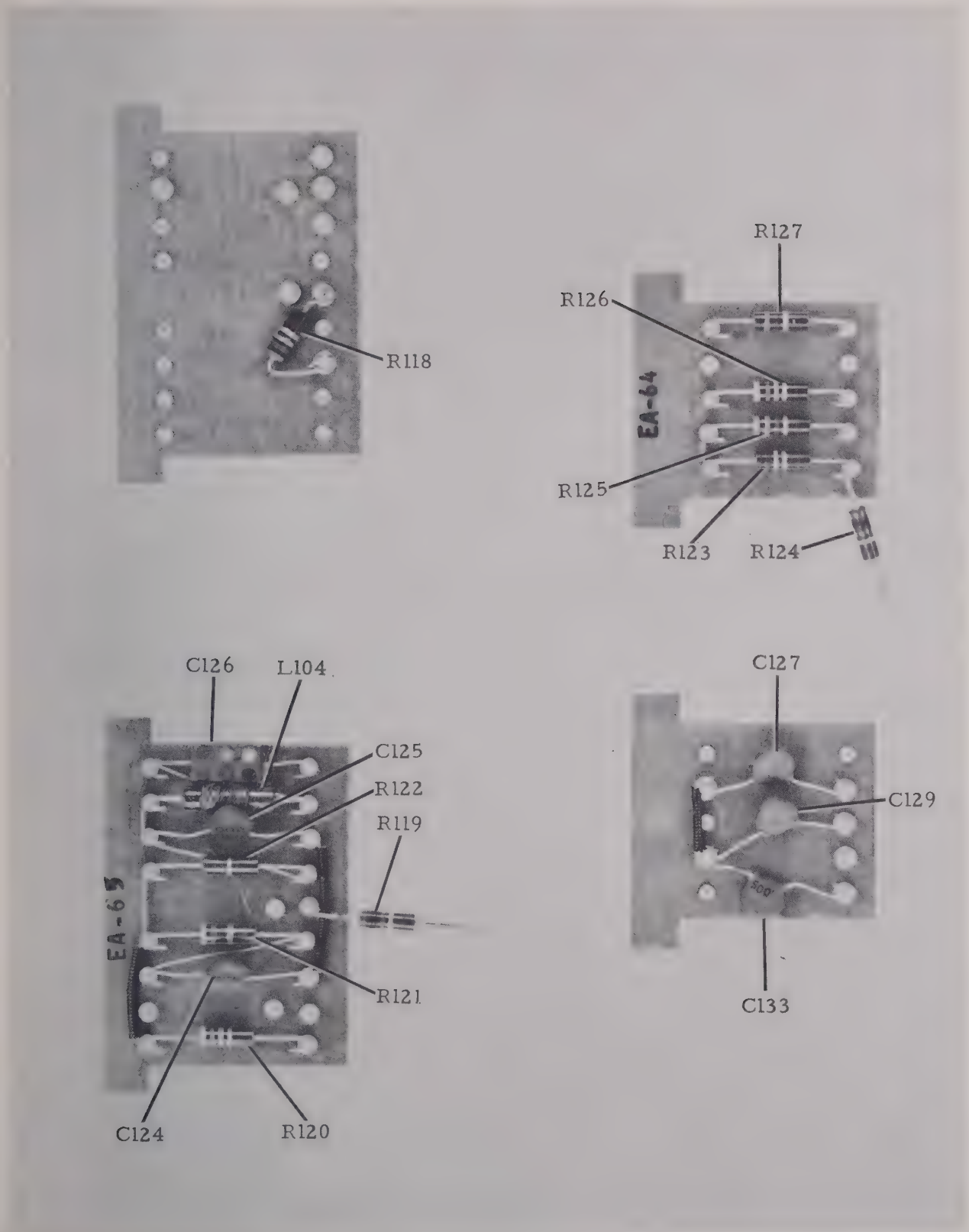


FIG. 22. BOARD ASSEMBLY EA64, EA65

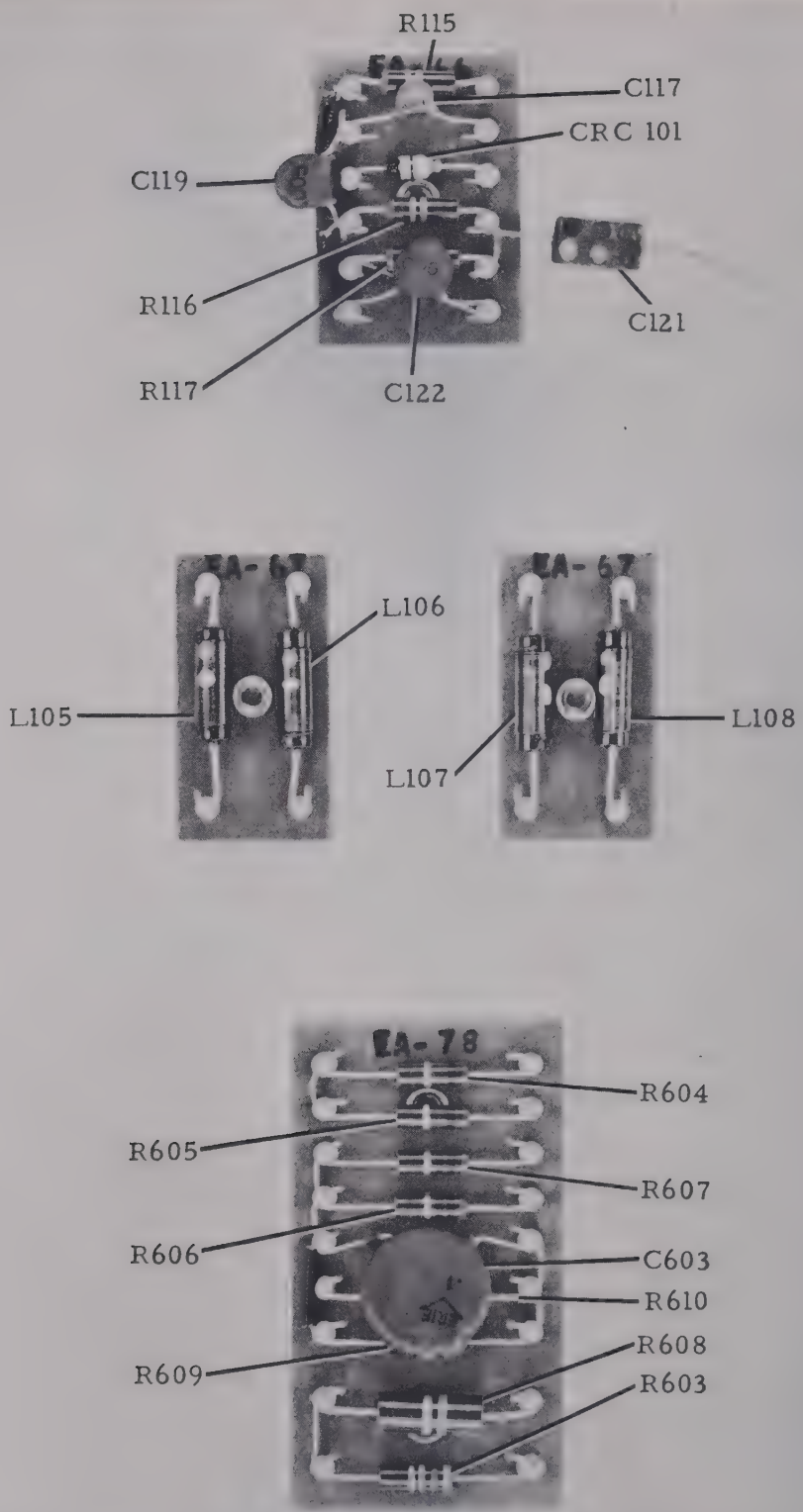


FIG. 23. BOARD ASSEMBLY EA66, EA67, EA78

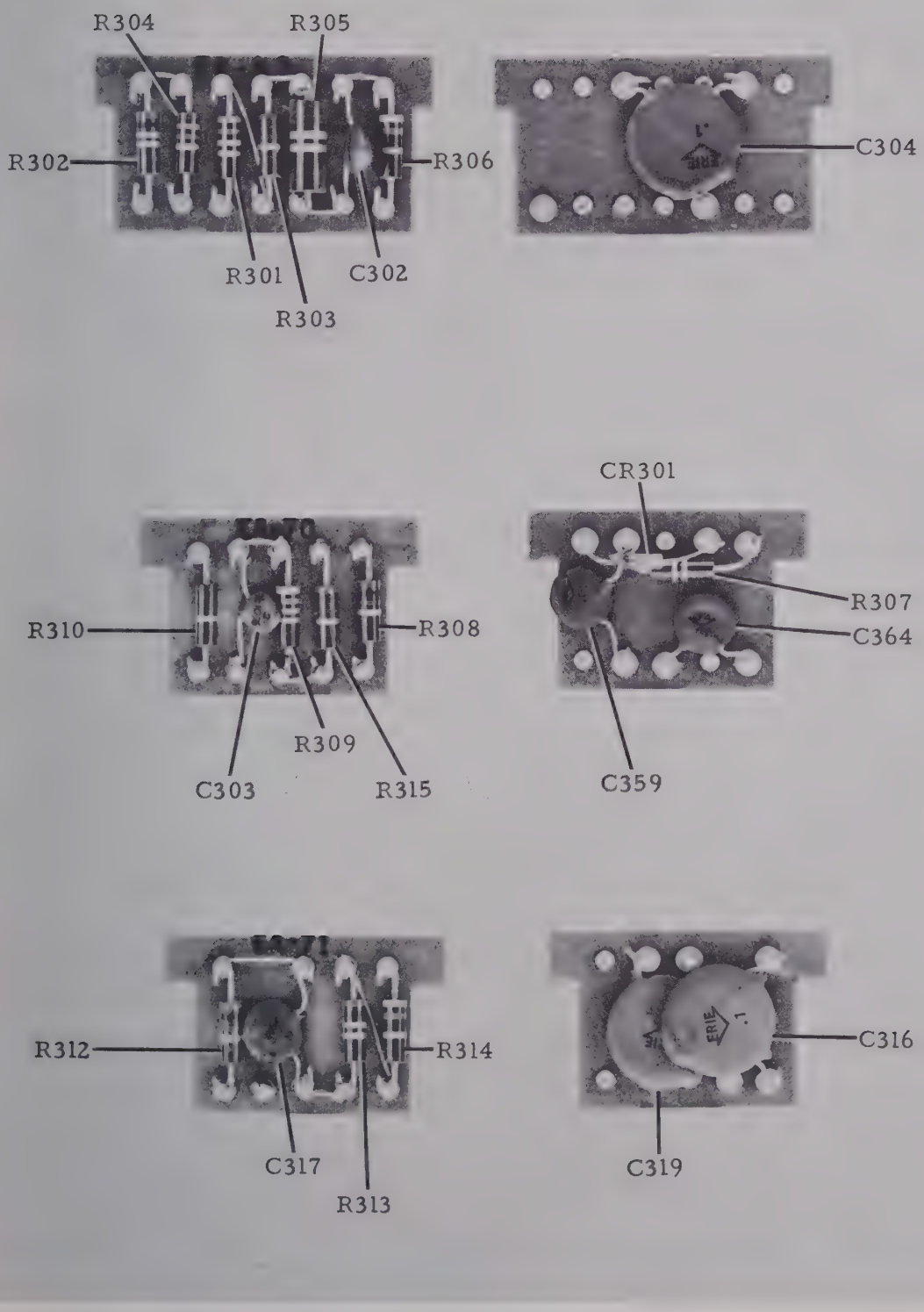


FIG. 24. BOARD ASSEMBLY EA69, EA70, EA71

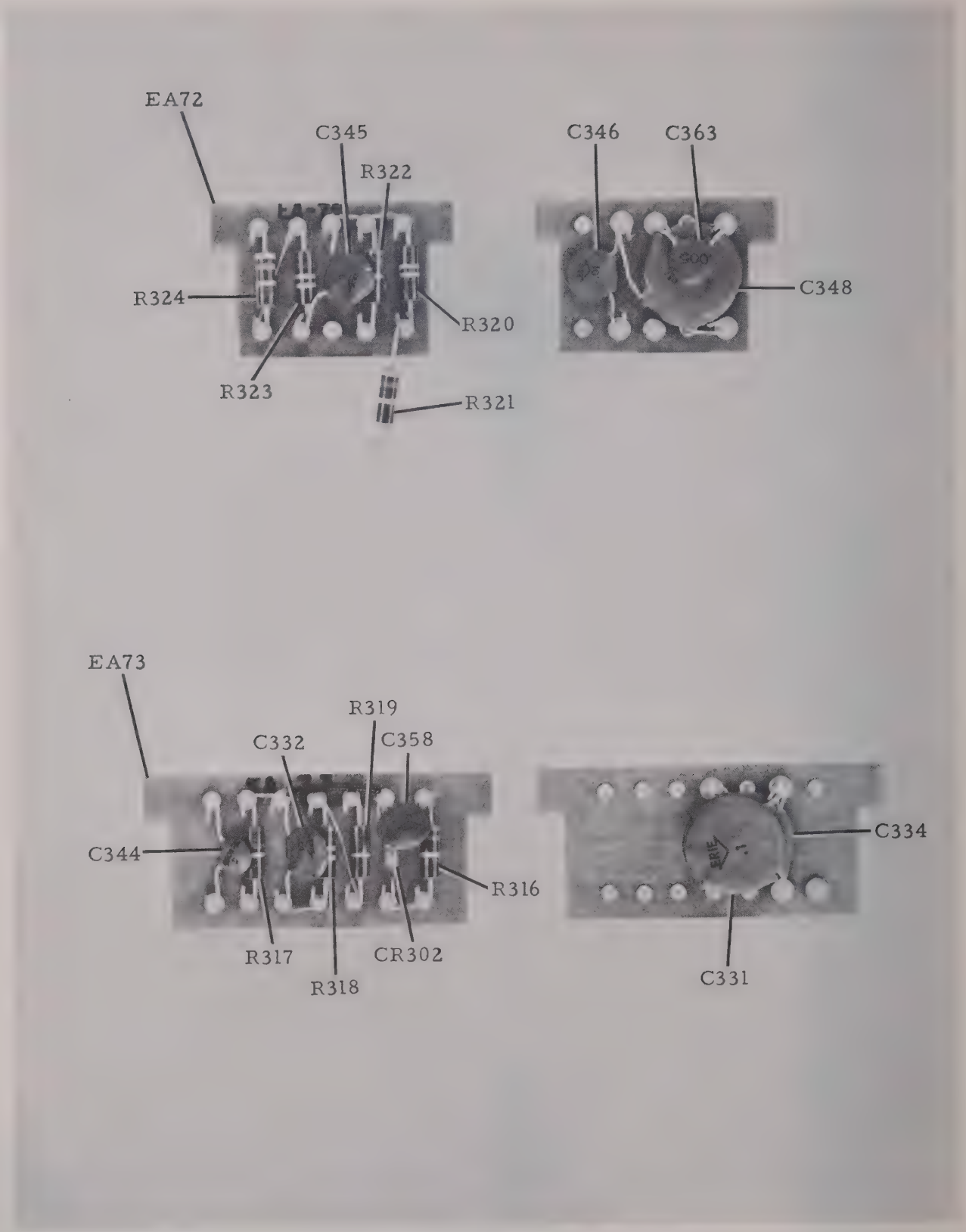


FIG. 25. BOARD ASSEMBLY EA72, EA73

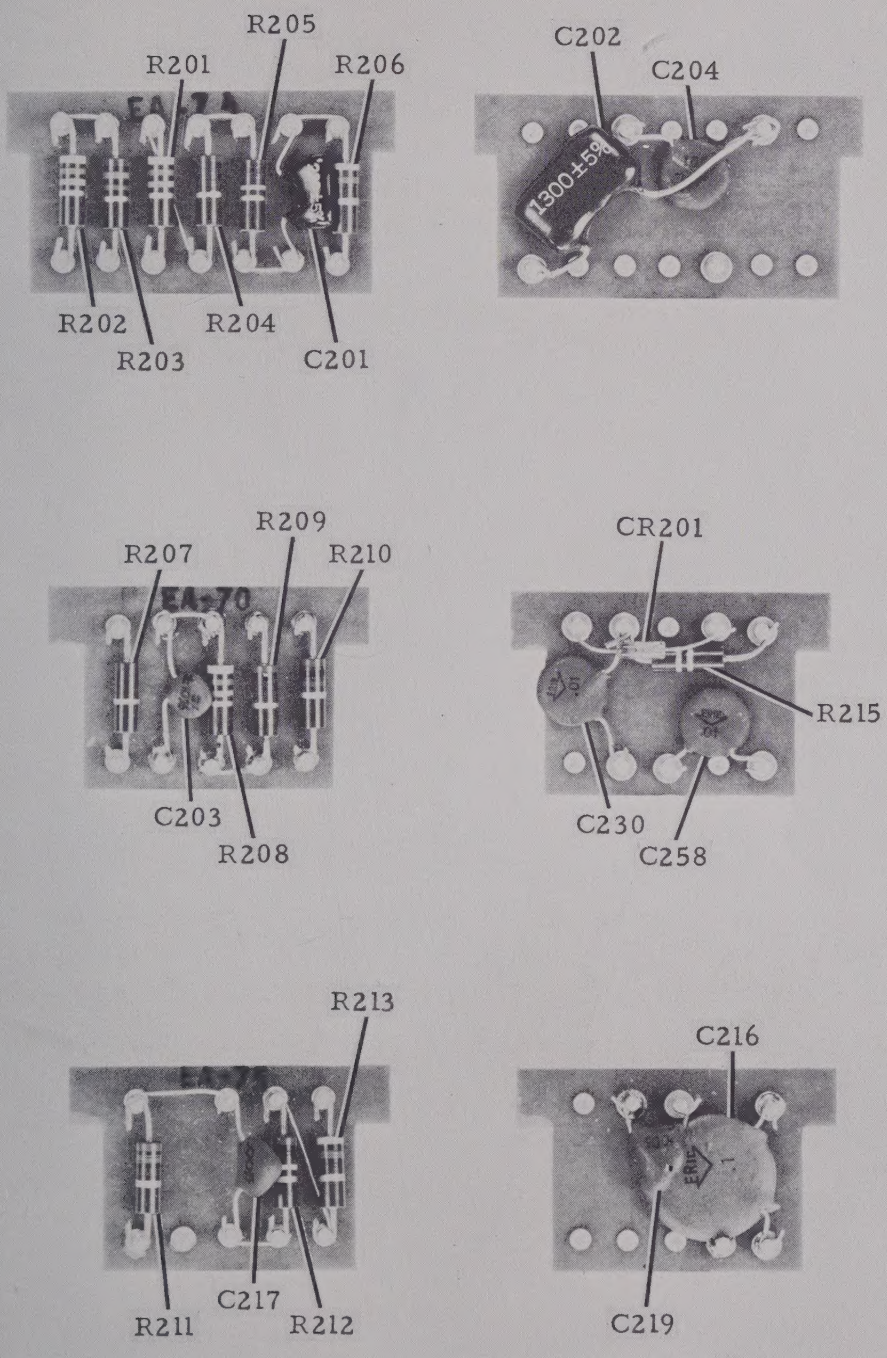


FIG. 26. BOARD ASSEMBLY EA74, EA70, EA75

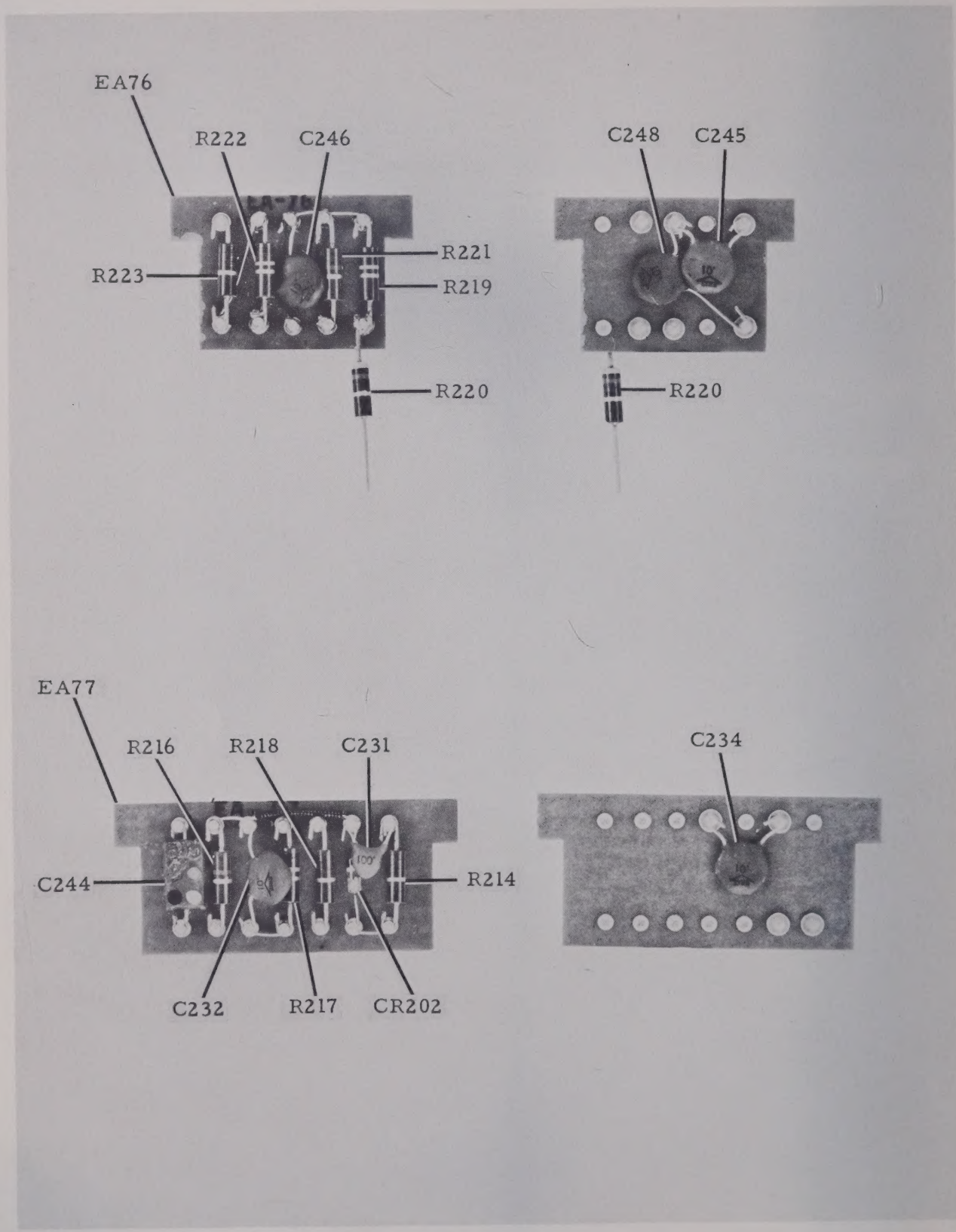


FIG. 27. BOARD ASSEMBLY EA76, EA77

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